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College of Agriculture
Agricultural Experiment Station

**FORTY-THIRD ANNUAL
REPORT**

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*In cooperation with United States Department of Agriculture, Bureau of Biological Survey.

†In cooperation with Sporting Arms and Ammunition Manufacturers' Institute.

‡In cooperation with United States Department of Agriculture, Bureau of Public Roads.

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FOREWORD

The eight annual reports of the Arizona Agricultural Experiment Station, from 1924 to 1931 inclusive (Nos. 35 to 42 inclusive), were not published. With this issue we are resuming the publication of the Annual Report Series. The annual financial statements of this Experiment Station for the years indicated above can be found in the Annual Reports of the Board of Regents of the University of Arizona which were published each year in the "University of Arizona Record."

THE DIRECTOR.

FORTY-THIRD ANNUAL REPORT

ADMINISTRATION

P. S. BURGESS

INTRODUCTION

As in past years, the research work of the Agricultural Experiment Station including the substations has been conducted on the project basis. These projects include studies in 11 distinct fields of rural endeavor. In the report which follows the research projects of the departments are listed and the results which have been secured during the past year are briefly summarized.

It has been felt for some time that the publications of the Agricultural Experiment Station might be more effectively distributed over the State. The research work which is being done for the farmers and ranchers of Arizona cannot be put to practical use unless our bulletins and circulars reach those who are interested. Furthermore, a wide circulation of our published material should be welcomed by our bankers, chambers of commerce, libraries, and other public-service institutions, for all of our population is either directly or indirectly interested in the welfare of agriculture and in every attempt which is being made to aid and improve this essential industry. We should attempt not to conserve these publications but to get them into the hands of all who can use them and derive benefit from them. With these ends in view we are revising and enlarging our mailing lists. In the future, not only will the annual lists of available publications be sent to a larger percentage of our population, but also brief abstracts of all new bulletins will be furnished.

CHANGES AND ADDITIONS

This is the first Annual Report to appear since 1923, and a number of important changes have taken place since that date. Professor J. J. Thornber resigned as Dean and Director in 1928 and was followed by Dr. E. D. Ball who, in turn, resigned in 1931. The Prescott Dry-Farm which had been conducted for over 20 years as an integral part of the Experiment Station was discontinued in 1929.

In January, 1930, the Yuma Valley Date Palm and Horticultural Station, comprising 39 acres located 2 miles south of Yuma, was exchanged for 95 acres of valley land 9 miles from Yuma and adjoining the mesa on Avenue B. The land lies immediately under the United States Reclamation Canal, making the water readily accessible to all parts of the farm. The location is within 1 mile of the Yuma Mesa Citrus Experiment Station which facilitates the problem of management and operation. Fifteen acres were planted to pecans in March, 1931, and 10 acres to dates in May of the same year. These plantings are being used for field-plot studies of orchard-management problems. The land had been cropped to cotton for a number of years which made it desirable to put most of it into alfalfa to improve fertility. A considerable area is now being used for cultural and plant-breeding studies with field crops. A modern five-room dwelling was completed in April, 1931, with funds representing the difference in value of the two properties exchanged. The plans for the dwelling, prepared by a Tucson architect, won national recognition in an exhibit of farm-home plans submitted from all parts of the United States. The design was especially prepared to fit the climatic conditions prevailing in the Yuma district. A combined office, laboratory, and garage-building was completed in the spring of 1932. The laboratory is equipped for handling the extensive soil-moisture studies being conducted at the Mesa Station as well as for studies of a botanical and chemical nature. Sleeping quarters are provided in the second story of this building for staff members when on field assignment.

The Citrus Experiment Station on the Yuma Mesa also has been greatly enlarged in scope. Over 31 acres have now been planted to grapefruit for irrigation and fertilization experimental work besides the original planting of 15 acres. Date palms of different varieties have also been added.

A number of improvements have been made at the Date Garden at Tempe since the last Annual Report was issued. A laboratory and office building, 30 feet by 50 feet, was constructed in 1930 at a cost of \$2,000. This contains two electrically heated processing rooms equipped with thermostatic controls, a Friez electric oven, Becker analytical balance, water still, Flamo gas installation, and miscellaneous equipment for laboratory work on soil-moisture and on date-processing methods. The dwelling at the Garden was completely remodeled during the same year at a cost of \$1500. For 2 years following the destruction by fire of the packing house at this Station in 1927, the date crop from the Garden was processed and packed in a leased building in Tempe. The 1930 and 1931 crops were sold on the palms to a group of growers who processed their

fruit cooperatively. This group is not functioning in 1932, which necessitates the limiting of fruit production at the Station to palms of the more important commercial varieties which are being used for various field and processing experiments. The fruit is no longer sold. Of the 15 acres on the Station, including some 78 varieties, only 48 palms of 13 varieties were pollinated in the spring of 1932. A much more intensive research program has been undertaken since the change in policy obviating the necessity of handling the commercial crop of fruit.

In May, 1924, the College of Agriculture acquired a new farm in Tucson about $4\frac{1}{2}$ miles northwest of the University Campus on the Tucson-Casa Grande Highway. It consists of 173 acres, of which 150 acres are irrigable and own water rights in the Flowing Wells Irrigation District. This farm was donated to the College of Agriculture by the Tucson Chamber of Commerce, made possible by the City of Tucson and Pima County. Since its acquisition, a new woven-wire fence with steel posts has been built entirely around the outside boundary. All of the fields were rearranged and re-leveled and an underground, concrete irrigation pipe line was constructed. This pipe line carries water to most of the fields but more construction is needed. A new 16-inch well was drilled to a depth of 150 feet. It was equipped with a Pomona deep-well cylinder pump of 100 gallons per minute capacity. An elevated steel tank of 30,000 gallon capacity was constructed to furnish a domestic water supply and for fire protection. An open-sided hay barn and a pump house were built during the year 1927-28. Recently the old adobe dwelling on this farm has been completely rebuilt and modernized. This farm is used both for research work by the departments of Agronomy and Horticulture, and for instructional purposes. The old University Farm at Tucson has recently received several very necessary repairs and improvements. The three dwellings on this property have been properly restored and painted. The barns, out-buildings, and corrals have been painted, and new hog houses and yards have been built to replace the old quarters. There was also completed during the past year a new milk house, including a modern refrigerating plant. A new DeLaval milker was also installed.

A branch chemical laboratory was located in the Arizona Producer Building, Phoenix, in 1929 for the purpose of analyzing samples of soils, irrigating waters, feeds, and fertilizers for the farmers of the Salt River Valley, and giving advice through the County Agent's Office to the farmers and ranchers, based upon this analytical work.

Few changes of a material nature, aside from necessary replacements to machinery and equipment, have been made either at the Mesa Experimental Farm or on the Campus at the University of Arizona.

TECHNICAL SERVICES RENDERED TO FARMERS

The farmers and ranchers of Arizona depend upon the Experiment Station to supply certain services requiring knowledge and skill in laboratory technique. The staff annually answers thousands of letters relating to agricultural practices, giving advice and information.

During the past fiscal year two, and sometimes three, chemists have been required to analyze the miscellaneous samples which have been submitted by citizens of this State. No charge whatever is made for this service. It has grown to such an extent that it became necessary 3 years ago to establish a branch laboratory at Phoenix to meet the increasing demands. Most of the samples submitted are soils, irrigating waters, fertilizers, and feeds. In any arid district where irrigation is practiced, a farmer should keep close check on the alkali content of his soils and irrigating waters and for this reason there is a great demand for this sort of work in this State. We have compiled a table which is herewith submitted showing the number of samples analyzed during the past fiscal year, their nature, and the approximate value of this work to the State. As will be seen, this work has meant a saving to the farmers of approximately \$32,000, during the past year. This estimate is based on conservative figures, as only the minimum prices charged by commercial chemical laboratories for such work were used in our calculations.

TABLE SHOWING SAMPLES ANALYZED FOR CITIZENS OF THE STATE DURING THE PAST YEAR AND APPROXIMATE VALUE OF THIS WORK.

	Tucson		Phoenix		Total No. of samples	Total value
	No. of samples	Values	No. of samples	Value		
Soils, alkali analyses.....	615	\$ 9,225	641	\$ 9,615	1,256	\$18,840
Soils, moisture equivalents....	171	855	14	70	185	925
Water analyses.....	540	8,100	75	1,125	615	9,225
Feeds, complete analyses.....	15	225	8	66	23	290
Cottonseed meal.....	37	185	16	80	53	265
Fertilizers:						
Complete analyses.....	10	100			10	100
Manures, stable.....	53	265	12	60	65	325
Bat guanos.....	30	150	25	125	55	275
Poison cases, cattle.....	15	75			15	75
Sugar beets.....	36	108			36	108
Miscellaneous materials..... (Bees, minerals, honey, range grasses, tankage, vinegar, plants, etc.)	376	1,880	9	75	385	1,955
Total	1,898	\$21,168	800	\$11,215	2,698	\$32,383

Infectious abortion in dairy cattle is a problem of serious economic importance to our dairymen. The Department of Dairy Husbandry is doing all it can to assist in eliminating this disease. Forty-three herds, representing a total of 1,225 cows, have been tested during the year, more than 3,000 separate tests having been made. While this is being done without cost to the dairymen, commercial pathological laboratories charge from \$1 to \$3 per test for such work. This Department also has supervision over all Advanced Registry testing in Arizona. This work consists in weighing the milk from each test cow on 1 or 2 days of each month throughout the lactation period, and testing all samples for butter-fat percentages. All reports are submitted to the national breed associations of the several breeds. Dairymen thus obtain authenticated records of production, and animals making high records are admitted to advanced registration by the several pure-breed associations. During the year ten breeders of purebred dairy stock applied for this service and 98 cows were tested.

Besides these services, the Department of Plant Pathology identifies hundreds of plant diseases and recommends remedies; the Departments of Horticulture and Agronomy make many viability tests of seeds and grains; the Departments of Animal Husbandry and Poultry Husbandry diagnose animal and poultry diseases; the Department of Entomology and Economic Zoology examines specimens submitted carrying insect pests injurious to plants and animals; the Department of Botany identifies hundreds of plants sent in for this purpose. The other departments also furnish information when requested.

EGG-LAYING CONTEST

The Experiment Station would hardly be justified in conducting this work merely as an egg-laying contest if it were not for the fact that much valuable information annually is obtained which relates directly to the several phases of poultry production. The results secured show whether or not poultry can be made to pay; they indicate the best breeds for local conditions, and sources of breeding stock; they offer a valid comparison between Arizona stock and that from other sections of the United States, and give opportunity for housing and feeding trials. The publicity given to the results secured also interests the public in the possibilities of poultry husbandry as a profession. The eleventh annual contest was conducted during the past fiscal year. A progressive interest in the work has been constantly manifested. It

may be of interest to state that, of the 40 or 50 egg-laying contests held each year in the United States and Canada, Arizona has never been below ninth place and one year came out in second place. The following table shows the average number of eggs laid per bird per year in Arizona contests compared with the grand average for the United States and Canada, since the year 1923-24. This year 20 entries finished the contest which was won by a pen of single-comb White Leghorns owned by the Gold Spot Hatchery (William Sprietsma) of Phoenix. It should be stated that these egg-laying contests are entirely self-supporting.

Year	Arizona, Average per bird Eggs	Other contests in U.S.A. and Canada, Average per bird Eggs
1923-24	204.9	181.1
1924-25	191.4	171.6
1925-26	205.8	173.4
1926-27	213.4	191.3
1927-28	212.8	185.1
1928-29	211.3	190.5
1929-30	202.0	188.1
1930-31	195.2	191.2
1931-32	188.6	—

COOPERATION WITH OTHER AGENCIES

As agricultural research progresses, and the problems involved become of greater scope and more difficult, the need for cooperation both between departments within the Station and also between the Station and other outside research agencies becomes increasingly desirable. At present a number of projects are receiving joint attention from the Arizona Agricultural Experiment Station and the following divisions of the United States Department of Agriculture: in plant nutrition and in soil studies, with the Office of Western Irrigation Agriculture, Bureau of Plant Industry; state soil survey, with the Bureau of Chemistry and Soils; soil and moisture studies with citrus, with the Bureau of Agricultural Engineering; range rodent studies, with the Bureau of Biological Survey; study of small grains, with the Office of Cereal Crops and Diseases, Bureau of Plant Industry; study of staple length of Arizona cottons, Division of Cotton Marketing, Bureau of Agricultural Economics. The Station also cooperates whenever possible with the State Commission of Agriculture and Horticulture, the State Live-

stock Sanitary Board, the State Fair Commission, the Arizona Fruit and Vegetable Standardization service, the Federal Predatory Animal and Rodent Control Service, the Federal Forest Service, and the Boyce Thompson Southwestern Arboretum.

STAFF CHANGES

With the exception of several internal changes, the personnel of the Agricultural Experiment Station Staff has undergone few changes during the past year. Dr. E. D. Ball, Dean and Director, resigned September 1, 1931, and was appointed Professor of Economic Zoology and Economic Zoologist. Dr. P. S. Burgess, formerly Professor of Agricultural Chemistry and Agricultural Chemist, was appointed Dean and Director October 24, 1931. Mr. W. T. McGeorge, formerly Soil Chemist, was promoted to Acting Agricultural Chemist, December 15, 1931. Mr. Charles A. Hobart, formerly Research Assistant in Agronomy, was appointed Superintendent of the University Farms, July 1, 1932. Mr. I. A. Briggs, formerly Assistant Professor of Agronomy and Assistant Agronomist, was promoted to Associate Professor of Agronomy and Associate Agronomist, July 1, 1932. Dr. R. L. Matlock was appointed Assistant Professor of Agronomy and Assistant Agronomist on June 1, 1931. He took the place of Mr. S. P. Clark, resigned. Dr. A. H. Finch was appointed Assistant Professor of Horticulture and Assistant Horticulturist on August 1, 1931. He took the place of Mr. D. W. Albert, who was permanently transferred to the Date Garden at Tempe where excellent facilities for the intensive study of date problems have been installed.

LEAVES OF ABSENCE

Ernest B. Stanley, M.S., Professor of Animal Husbandry and Animal Husbandman, was on sabbatical leave during the past year studying toward the degree of doctor of philosophy at the University of Wisconsin.

Ralph S. Hawkins, M.S., Professor of Agronomy and Agronomist, was on sabbatical leave during the past year. He completed his work, for the doctor of philosophy degree at the University of Wisconsin.

William G. McGinnies, B.S., Associate Professor of Range Ecology and Range Ecologist, was on sabbatical leave during the second half-year studying toward the doctor of philosophy degree at the University of Chicago.

Malcolm F. Wharton, M.S., Assistant Professor of Horticulture and Assistant Horticulturist, was on sabbatical leave during the past year studying toward the doctor of philosophy degree at the University of California.

Rubert B. Streets, Ph.D., Associate Professor of Plant Pathology and Associate Plant Pathologist, was on sabbatical leave during the first half-year working on research problems at the Citrus Experiment Station, Riverside, California.

PUBLICATIONS

TECHNICAL BULLETINS

No. 33, "Studies in Lettuce Seedbed Irrigation Under High Temperature Conditions," by M. F. Wharton and Charles Hobart, Sept. 1, 1931.

No. 34, "The Vitamin Content of Three Varieties of Dates," by M. C. Smith and L. A. Meeker, Oct. 1, 1931.

No. 35, "Phosphate Solubility Studies on Some Unproductive Calcareous Soils," by W. T. McGeorge and J. F. Breazeale, Oct. 15, 1931.

No. 36, "The Relation of Phosphate Availability, Soil Permeability, and Carbon Dioxide to the Fertility of Calcareous Soils," by W. T. McGeorge and J. F. Breazeale, Nov. 1, 1931.

No. 37, "Irrigation Investigations in Young Grapefruit Orchards on the Yuma Mesa," by G. E. P. Smith, A. F. Kimmison and A. G. Carns, Dec. 15, 1931.

No. 38, "Electrodialysis as a Measure of Phosphate Availability in Soils and the Relation of Soil Reaction and Ionization of Phosphates to Phosphate Assimilation," by W. T. McGeorge, March 1, 1932.

No. 39, "The Movement of Gases Through the Soil as a Criterion of Soil Structure," by T. F. Buehrer, June 1, 1932.

No. 40, "Studies on Iron, Aluminum and Organic Phosphates, and Phosphate Fixation in Calcareous Soils," by W. T. McGeorge and J. F. Breazeale, June 15, 1932.

No. 41, "Nutritional Disorders in Alkaline Soils as Caused by Deficiency of Carbon Dioxide," by J. F. Breazeale and W. T. McGeorge, June 22, 1932.

No. 42, "The Physico-Chemical Relationships of Soil Phosphates," by T. F. Buehrer, June 30, 1932.

GENERAL BULLETINS

No. 138, "Control of the Harvester Ant," by A. A. Nichol, Sept. 15, 1931.

No. 139, "Cost of Producing Field Crops in the Salt River Valley, Arizona, 1928," by S. P. Clark, Oct. 1, 1931.

No. 140, "The Pecan in Arizona," by A. F. Kinnison and A. H. Finch, July 1, 1932.

PAPERS IN TECHNICAL JOURNALS

Ball, E. D., "Some New North American Genera and Species in the Group Formerly Called *Platymetopius* (*Rhynchota Homoptera*)." Part I in Canadian Ent., 63, (Oct. 1931), pp. 216-22; Part II in Canadian Ent., 63, (Nov. 1931), pp. 224-228.

Ball, E. D., "New Species of *Phlepsius* with Notes on Others," in Pan-Pacific Entomologist, v. 8 (1931), pp. 85-89.

Ball, E. D., "New Genera and Species of Leafhoppers Related to *Scaphoideus*," in Jour. Wash. Acad. Sci., v. 22 (1932), pp. 9-19.

Ball, E. D., "A Monographic Revision of the Treehoppers of the Tripe *Telamonini* of North America," in Ent. Americana, 12 (1932), pp. 1-68, plates 1-4.

Ball, E. D., "Some New Treehoppers from the South and Southwest," in Proceedings Biol. Soc. Wash., v. 45 (1932), pp. 75-82.

Ball, E. D., "Some Major Celery Insects of Florida," Bul. 250, Florida Agr. Exp. Sta. (June, 1932).

Finch, A. H., "Anatomical Differences in Pecan Varieties that Fruit Differently," in Proc. Am. Soc. for Hort. Sci. (1931).

Greene, R. A., "The Effect of Temperature Upon Nitrogen Fixation by *Azotobacter*," in Soil Sci., v. 35 (1932), p. 153.

Greene, R. A. and Reynard, Chas., "The Influence of Two Burrowing Rodents, *Dipodomys spectabilis* (kangaroo rat) and *Neotoma albigula* (pack rat), on Desert Soils in Arizona," in Ecology, v. 21 (1932), p. 73.

Greene, R. A., "The Composition of the Fiber and Waste of *Agave lechugilla*, *Torreyi*," in Botanical Gazette, v. 93 (1932), p. 484.

Hawkins, R. S., "Methods of Estimating Cotton Fiber Maturity," in Jour. Agr. Res., v. 43 (Oct. 15, 1931), pp. 733-742.

McGeorge, W. T., "Chemically Equivalent Base Exchange Reactions in Plants," in Plant Physiology, v. 7 (1932), p. 119.

Smith, G. E. P., "Effect of Irrigation on Soil Temperature," in Citrograph, XVII, p. 7, May, 1932.

Smith, Margaret C., Lantz, E. M., and Smith, H. V., "The Cause of Mottled Enamel," in Jour. Dental Res., v. 12 (Feb. 1932), pp. 149-159.

Smith, Margaret C. and Lantz, E. M., "The Cause of Mottled Enamel," in Dental Survey, March, 1932.

Smith, Margaret C. and Lantz, E. M., "Changes in the Incisors of Rats Fed a Vitamin-A-Deficient Ration," (Preliminary Report), in Jour. Dental Res., v. 12 (June, 1932), p. 556.

Smith, Margaret C. and Lantz, E. M., "Studies in the Metabolism of Fluorides I. The Effect of Fluorides upon the Chemical Composition of the Incisors of Albino Rats." (Preliminary Report), in Jour. Dental Res., v. 12 (June, 1932), p. 552.

Smith, Margaret C. and Smith, H. V., "The Concentration of Fluorides in Drinking Water in Relation to the Occurrence and Severity of Mottled Enamel of Human Teeth," (Preliminary Report), in Jour. Agr. Res., v. 12 (June, 1932), p. 554.

Vorhies, C. T., "First Record of the Pectoral Sandpiper for Arizona," in The Condor, v. XXXIV (1932) pp. 46-47.

Besides the publications listed above, many informative articles have been contributed during the past year to the agricultural press of the Southwest by different staff members.

RESEARCH PROJECTS

AGRICULTURAL CHEMISTRY AND SOILS

W. T. McGEORGE, T. F. BUEHRER, J. F. BREAZEALE,
H. V. SMITH, R. A. GREENE.

No. 72, Soil, water, and alkali factors that govern the successful reclamation of alkali lands in the Salt River Valley (State).

No. 120, Studies on the composition, formation, and determination of base-exchange compounds in soils (Purnell).

No. 155, (See Department of Horticulture).

No. 160, Weather observations at the University of Arizona (State).

No. 161, The mechanism of ion absorption by plants as well as a study of the availability of plant nutrients in arid soils (Purnell).

No. 162, (a) A study of the soil:plant system with reference to the availability of water principally at or near the wilting point. (b) A study of the adsorption, passage, and exchange of gases in soils (Purnell, State).

No. 164, A microbiological study of Arizona soils (Purnell).

No. 165, A fundamental study of soil conditions inimical to crop production in semi-arid soils under irrigation (Purnell).

No. 169, A lysimeter study of the nitrogen balance in irrigated, arid soils (Purnell).

AGRICULTURAL ENGINEERING

G. E. P. SMITH, H. C. SCHWALEN, W. A. STEENBERGEN.

No. 1, A study of underground water movement and pressures, recharge, storage, and discharge of groundwater reservoirs; recovery by wells and underground collecting channels; limits of availability for irrigation (Adams).

No. 2, A study of pumping machinery to determine fundamental facts relating to the action and efficiency of various types of pumping machinery (Adams, State).

No. 35, The relation between evaporation rate and the duty of water for irrigation (Adams).

No. 129, Irrigation studies with the Marsh seedless grapefruit on the Yuma Mesa (Purnell, State): in cooperation with the Department of Horticulture.

AGRONOMY

R. S. HAWKINS, I. A. BRIGGS, R. L. MATLOCK.

No. 17, Cooperative crop experiments (State).

No. 62, The culture and development of Pima and Upland cotton (State).

No. 63, Study of varieties, culture, and improvement of forage crops such as sorghums and grasses (State).

No. 64, The culture and improvement of small grains including wheat, oats, barley, rye, etc. (State).

No. 65, The culture and improvement of legumes adapted to the Southwest (State).

No. 92, A study of cotton boll shedding (Purnell).

No. 110, A study of the effect of storage under arid conditions upon field crop seeds (State).

No. 113, Cotton production as affected by soil environment (Purnell).

No. 122, Wheat varieties for northern Arizona (State).

No. 133, Cost of producing field crops under irrigation in Arizona (Purnell, State).

No. 149, (See Department of Human Nutrition).

No. 152, (See Department of Human Nutrition).

No. 179, Time of cutting and methods of curing and handling alfalfa (Purnell).

ANIMAL HUSBANDRY

E. B. STANLEY AND E. L. SCOTT.

- No. 139, Fattening Arizona lambs (Mesa Farm) (State).
 No. 140, Fattening cattle in Arizona (Mesa Farm) (State).
 No. 171, Range livestock losses from poisonous plants (Purnell): in cooperation with the Department of Range Ecology.
 No. 172, A study of foraging habits of range cattle (Purnell): in cooperation with the Department of Range Ecology.
 No. 183, The nutritional deficiencies of Arizona range forages (Purnell, State).

BOTANY

J. J. THORNER

- No. 173, A study of the poisonous plants of Arizona (State).
 No. 174, Grasses and grass-like plants of Arizona (State).
 No. 175, Ornamental plants of Arizona (State).
 No. 176, A study of the Arizona cacti (State).

DAIRY HUSBANDRY

W. S. CUNNINGHAM AND R. N. DAVIS

- No. 70, The preservation of skimmed milk curd for poultry feeding (State).
 No. 119, Pasture of young calves (Hatch Sales).
 No. 144, A study of the stages of maturity of hairy Peruvian and common alfalfa hay on milk production (State).
 No. 146, Study of properties of sweet buttermilk powder (Purnell).
 No. 177, Study of infectious abortion in dairy cattle (State).
 No. 180, Physiological varieties of bacteria in milk at the time of reduction in the methylene blue reduction test (Purnell).

ENTOMOLOGY AND ECONOMIC ZOOLOGY

C. T. VORHIES, E. D. BALL, L. P. WEHRLE, A. A. NICHOL

- No. 24, Study of the life history of range rodents (Adams).
 No. 105, Studies on the scale insects, *Coccidae*, of Arizona (Purnell).
 No. 106, Study of the life history of the western green June beetle (Purnell).
 No. 163, Water requirements of desert animals (Adams).
 No. 178, Biology of range grasshoppers (Purnell).

HORTICULTURE

A. F. KINNISON, D. W. ALBERT, M. F. WHARTON, A. H. FINCH

No. 26, A study of the culture and management of date orchards (State).

No. 39, Pecan studies (State).

No. 49, Grape investigations (State, Hatch).

No. 129, (See Department of Agricultural Engineering).

No. 155, Fertilizer plot study of Marsh Seedless Grapefruit on the Yuma Mesa (Purnell, State): in cooperation with the Department of Agricultural Chemistry and Soils.

No. 166, An investigation of some orchard and soil management practices to determine fundamental factors influencing the premature decline of citrus orchards in Arizona (Purnell): in cooperation with the Bureau of Agricultural Engineering, U.S.D.A.

No. 181, Studies of pecan fruiting (Purnell).

No. 182, Date maturation and storage studies (Purnell).

HUMAN NUTRITION

MARGARET C. SMITH, GLADYS H. ROEHM, EDITH LANTZ

No. 149, The value of Arizona sorghum grains, hegari and yellow milo, compared with yellow corn as a source of vitamin A (Purnell): in cooperation with Department of Agronomy.

No. 152, The effect of sunlight on the curing process upon vitamin A and D contents of alfalfa hay (Purnell): in cooperation with the Department of Agronomy.

No. 153, The quantitative measure of the vitamin A, B, C, and G content of several varieties of Arizona dates (Purnell).

No. 167, The biological value of hegari proteins and the supplemental value of certain protein concentrates (Purnell).

No. 168, The relation of nutrition to "Mottled Enamel" endemic in certain Arizona communities (Purnell).

PLANT BREEDING

W. E. BRYAN AND E. H. PRESSLEY

No. 4, Inheritance of economic characters in pure lines of alfalfa (Adams).

No. 6, Wheat breeding studies (Adams).

No. 15, Date breeding studies (State).

No. 47, Cotton breeding studies (Adams).

PLANT PATHOLOGY

J. G. BROWN, R. B. STREETS, M. M. EVANS

- No. 40, Study of date-fruit rot (Adams).
- No. 41, Study of angular leaf spot of cotton (Adams).
- No. 42, Study of Texas root rot (Adams).
- No. 43, Miscellaneous studies in plant pathology (State).
- No. 58, Bacterial rot of lettuce (Adams).
- No. 107, Study of the life history of *graphiola*, and the control of *graphiola* leaf spot of palms (Purnell).

POULTRY HUSBANDRY

HARRY EMBLETON AND H. B. HINDS

- No. 46, Foundation for experimental work (State).
- No. 53, Egg-laying contest (State).
- No. 90, A comparison of certain local Arizona feeds (State).
- No. 91, Poultry housing experiments (State).

RANGE ECOLOGY

W. G. MCGINNIES AND A. A. NICHOL

- No. 123, An ecological study of vegetation on a selected number of sheep and goat ranges in Arizona (Purnell).
- No. 135, Control of rayless goldenrod on Arizona ranges (Purnell).
- No. 136, A study of the relative amounts of range forage consumed by cattle and by rodents under southern Arizona range conditions (Purnell).
- No. 170, The measure of the relative influence of factors determining the desert grass-land: desert savanna type of vegetation and of the individual species or other components within that type (Purnell).
- No. 171, (See Department of Animal Husbandry).
- No. 172, (See Department of Animal Husbandry).

DEPARTMENTAL REPORTS

AGRICULTURAL CHEMISTRY AND SOILS

W. T. McGEORGE

The activities of the Department of Agricultural Chemistry have been devoted during the past year to research in soils, plant nutrition and related problems, and to the examination of soil, water, and miscellaneous samples sent to this laboratory for analysis by citizens of the State.

The soils of Arizona are young, agriculturally speaking. That is, they have not been intensively cropped for so long a period as soils of the eastern United States. Then too the types existing in this State are peculiarly characteristic. Methods used in treating Eastern or Midwestern soils are not always applicable in Arizona.

There is much need therefore for investigational studies looking toward a clear knowledge of Arizona soil properties and the nutrition of crops grown upon them. The types of research which these problems demand may be divided into two classes. In the one case the research investigations are of direct economic value to the farmer and may be classed as experimental research. In the other case the research is purely fundamental and while to many it may appear to be of little or no direct economic value, it is an extremely essential aid to the successful solution of directly economic investigations of whatever nature. A workman must know his tools. For example, we should not only know what fertilizers or what soil treatments are needed but why they are required. In other words, fundamental research is the key to a clear understanding and interpretation of the experiments of direct economic application and to the explanation of the abnormal behavior of crops so often noticed by the observing farmer. Therefore it has been our aim to keep these two fields of research work closely coordinated and properly balanced.

Studies on the composition, formation, and determination of base exchange compounds in soils (No. 120 P)*. During the past year work on this project was devoted entirely to base exchange studies on green manures and plant materials. A paper entitled "Chemical Equivalent Base Exchange Reactions in Plants" was published in *Plant Physiology*. This paper covered an investigation of exchange reactions in alfalfa as related to cell permeability and equilibrium conditions in the cell sap as well as the building up of the exchange capacity of

*The letters following the numbers refer to P—Purnell, A—Adams, H—Hatch, and S—State. Thus, No. 120 P means Purnell Project No. 120. Purnell, Hatch, and Adams funds come from the Federal Government.

the soil by green manuring. We are now studying the exchange properties of plant roots. The studies conducted under this project show the feasibility of building up the fixing power of the soil (this prevents loss of fertilizer by leaching) by use of organic manures

Mechanism of ion absorption by plants as well as a study of the availability of plant nutrients in arid soils (No. 161 P). A great deal of time has been devoted to this project during the past year but it has been largely included in our report on project No. 165 P because of its direct relation to the fertility studies embodied in that project. The results obtained have shown that infertility in alkaline soils is largely due to the inability of the plant to absorb phosphates and nitrates in the presence of high alkalinity. In fact data obtained in this work have led us to conclude that black alkali is not the cause of infertility in black-alkaline soils as it is usually not present in sufficient concentrations to cause this condition. Non-absorption of plant food, until the roots have lowered the alkalinity of the soil solution by exudation of carbon dioxide, is the principal factor depressing plant growth.

Study of the soil-plant system with reference to the availability of water principally at or near the wilting point together with a study of the absorption, passage, and exchange of gas in soils (No. 162 P). Studies involving the growth of plants in soils approximating the wilting point have been continued. In this work much new technique has been developed to illustrate and prove that plants may transport water from the subsoil to higher levels or even the surface soil and utilize this transported water not only in increasing the moisture content of the surface soil, but even in developing feeder roots which function in supplying the plant with food from the surface soil. Progress on the second part of this project is yielding a fund of information on soil structure and related physical phenomena. Two technical bulletins have already been published on this project. The last one appeared during the past fiscal year as No. 39. A brief abstract follows: "Movement of Gases Through the Soil as a Criterion of Soil Structure." This publication presents a study of the laws governing the movement of air, carbon dioxide, and water vapor through the soil, in so far as it is related to soil structure. It is recognized that the soil "breathes" as a result of atmospheric changes, and that the oxygen:carbon-dioxide interchange is important to root growth. The structural characteristics of the soil as shown by particle arrangement cannot be directly determined, but can be measured only in terms of some other process which depends upon such arrangement. The flow of air offers a convenient method of measuring a structure constant for soils in terms of such factors as

effective particle size, humidity of the air, the dimensions of the container, and the pressure drop through the sample. The smaller the size of particle and the greater the degree of compaction, the slower will be the rate of flow and *vice versa*. An apparatus was designed and perfected which affords close control of these factors and yields characteristic constants for various granular materials, such as shot, standard soil separates, and soils. Tight soils offer high resistance to air movement, even though the percentage porosity is great, because of the fineness of the pores. If the particles are larger, the amount of air passing through in any given time is often less than expected, indicating that although the channels are relatively larger in mean diameter, they are not all continuous. The dead air spaces or "blind alleys" are not effective in permitting free gas interchange. Structure is therefore defined in terms of the flow of air, since such flow represents a passage through only the continuous open channels and therefore contributes most vitally to plant nutrition. Numerous experiments made with soil separates of various sizes, both stratified and mixed, show that the constants obtained are most significant and characteristic when the soil sample is mixed as uniformly and compacted as closely as possible.

A microbiological study of Arizona soils (No. 164 P). The study of non-symbiotic nitrogen fixation in arid soils has been continued during the past year and the investigation extended to include symbiotic fixation with particular reference to active desert plants. Some other phases of soil microbiology have also been given attention. A large part of the completed work is embodied in three papers which have been published.

"The Effect of Temperature upon Nitrogen Fixation by *Azotobacter*." This paper has been published in *Soil Science*. The purpose of this investigation was to determine the effect of high soil temperatures, which exist in Arizona soils during the summer, upon the activities of the nitrogen-fixing *Azotobacter*. It showed that Arizona soils have an active *Azotobacter* flora which fixes nitrogen at higher temperatures than do the same organisms from soils of more temperate regions. The optimum temperature for fixation was 32.5° C., the maximum 42.5° C., but there was active fixation by the cultures from Arizona soils at 40.0° C.

"The Applicability of the *Azotobacter* (plaque) Method for Determining the Fertility Requirements of Arizona Soils." This paper also appeared in *Soil Science*. This method has been used with considerable success on certain Western soils as a rapid method of determining their fertilizer requirements. A great deal of time has been spent therefore in determining its value for Arizona soils. A careful trial of the method

as used by its advocates, even after numerous modifications, showed that it is of little or no value when used on the calcareous soils of this State.

"The Specific Reaction Rates and Temperature Quotients for the Fixation of Nitrogen by *Azotobacter*." In this paper some temperature effects on nitrogen fixation are presented from a physico-chemical aspect. An increase in temperature of 10° C. usually doubles the rate of chemical or biological reactions. It was found however that such an increase in temperature did not greatly increase the rate of nitrogen fixation.

A fundamental study of soil conditions inimical to crop production in semi-arid soils under cultivation (No. 165 P). Because of the immediate need for research on this project as well as its economic importance, more time has been devoted to it than to any of the others. The investigation has been confined largely to phosphate availability as specifically related to calcareous, alkaline soils because preliminary experiments indicated that this was a vital factor. This work has been discussed in six technical bulletins which have been published during the fiscal year. Brief summaries of these follow.

"Phosphate Solubility Studies on Some Unproductive Calcareous Soils," Technical Bulletin No. 35. This was the first bulletin of this series and dealt with solubility relations and availability of phosphates in many soils from fertile and unfertile areas of the State. The outstanding points in this bulletin were: A definite proof that phosphate deficiency is a characteristic of the poor soils, and that no chemical method of determining phosphate availability seemed to be suited to our alkaline calcareous soils.

"The Relation of Phosphate Availability, Soil Permeability, and Carbon Dioxide to the Fertility of Calcareous Soils," Technical Bulletin No. 36. The outstanding points in this bulletin were: 1. The vital importance of carbon dioxide, and the carbon-dioxide:oxygen balance, to the availability of phosphate in alkaline calcareous soils; 2. The deleterious effect of puddled soils and poor water permeability on phosphate availability; 3. The depression of phosphate solubility in soils in the presence of neutral salts (white alkali) and calcium carbonate; 4. The discovery of the carbonato-phosphate of calcium as the principal difficultly soluble form of phosphate in our calcareous soils.

"Electrodialysis as a Measure of Phosphate Availability in Soils and the Relation of Soil Reaction and Ionization of Phosphates to Phosphate Assimilation," Technical Bulletin No. 38. The first part of this bulletin presented a study of the adaptability of electrodialysis as a means of measuring the rate of ionization of phosphate in soils and

therefore indicating the availability of soil phosphates. An excellent agreement was obtained between field response to phosphate and rate of ionization. The second part presented some new theories and observations on the effect of soil reaction (pH) and ionization of orthophosphates on the absorption of phosphates by crops. It is shown therein that crops experience great difficulty in obtaining their phosphates in alkaline calcareous soils either because the plant prefers the H_2PO_4 ion, which is the dominant ion at acid reactions, or the fact that the presence of a high alkalinity interferes with absorption of phosphate by plants.

"Studies on Iron, Aluminum, and Organic Phosphates and Fixation in Calcareous Soils," Technical Bulletin No. 40. Black-alkali soils contain iron, aluminum, silica, and organic matter in the soil solution. This bulletin deals with the role of these factors in the availability and solubility of phosphate in alkaline calcareous soils and also deals with phosphate fixation by soils. The more important points are: Phosphates of iron, aluminum, and organic matter are readily absorbed by plants; with the exception of vivianite, the mineral phosphates are of little or no value to plants; the mineral phosphates are very insoluble when treated with carbon-dioxide solutions or electro-dialyzed; all the above forms of phosphate are more soluble at alkaline reactions than at acid reactions; plants cannot absorb these phosphates at high alkaline reactions even though they are present in solution in abundance until they have reduced the alkalinity of the solution; on reclaiming alkaline soils, the solubilities of these phosphates are reduced together with the alkalinity. Fixation studies showed that the fertilizer phosphates which are most readily soluble in water are the most suitable forms for Arizona soils as these maintain a higher concentration in the soil solution for a longer period.

"Nutritional Disorders in Black Alkali Soils as Caused by Deficiency of Carbon Dioxide," Technical Bulletin No. 41. Throughout our investigations, as given in the preceding abstracts, we became more and more convinced that the toxicity of black-alkali soils is not due to black alkali but rather due to the effect of the high alkalinity upon the absorption of plant food. This bulletin therefore deals with infertility of black-alkali soils from the standpoint of the handicap which the reaction of these soils imposes upon plant processes. It is shown in this bulletin that the actual amounts of black alkali which are present in black-alkali soils are amazingly small. For example at pH 10.0 there will be only 1 part per million hydroxyl ions, 2.3 parts per million sodium hydroxide or 6.8 parts per million sodium carbonate all of which are far less than toxic amounts. On the other hand, we show definitely that there can be no absorption of phosphate or nitrate by the plant at alkalinities

greater than pH 7.6 provided the nutrient solution is *maintained* at this reaction. There are two methods by which this handicap may be overcome in alkaline soils: By exudation of carbon dioxide from the roots of plants; and by the decomposition of organic matter in the soil, thereby neutralizing the hydroxide and lowering the reaction (pH) to a point where the plant can absorb its food. The complete absence or great deficiency of carbon dioxide in soils is the greatest factor concerned with the low fertility of alkaline soils and every method of reclamation (manure, gypsum, drainage) is in fact a means of getting carbon dioxide into the soil. Plant roots will elongate and the plants will transpire normally at reactions where phosphate or nitrate is not absorbed. Throughout this bulletin we have stressed our belief that more consideration should be given to the influence of alkali-soil characteristics on plant performance.

"The Physico-Chemical Relationships of Soil Phosphates," Technical Bulletin No. 42. The sixth bulletin of this series presents the fundamental theories involved in the behavior of soil phosphates. The value of any investigation is greatly enhanced by a theoretical confirmation of experimental observations and this is clearly evident from a perusal of the six bulletins issued on this project.

The amount of phosphate present in the soil solution in a form readily assimilable by the plant is determined by a number of complex and interrelated factors, and the most effective and economical fertilization procedure so far as phosphates are concerned must be based upon a clear understanding of these factors. This bulletin presents a study of the behavior of soil phosphates, as related to reaction changes, dissolved salts with or without a common ion, hydrolysis, and the energy required for absorption of phosphate by the plant under various conditions. It is shown why the plant feeds chiefly upon H_2PO_4 ions, and that the amount of this ion present in alkaline calcareous soils depends upon the concentration of hydroxyl ions in the soil solution and the ability of the plant to give off carbon dioxide through the roots to neutralize the alkalinity and convert HPO_4 into H_2PO_4 ions. The free energies of a number of soil phosphate reactions are calculated, and it is shown how these results may be applied in deciding which reactions will take place under a given set of conditions. The amounts of soluble phosphate present in various calcareous soils (calculated as dicalcium phosphate), were found to agree very closely with the results obtained by analysis. Neutral salts were found, as a rule, to increase phosphate solubility except when common ions were present or the soil contained free hydroxyl ions. An explanation based upon the electrical condition of the plant root in acid, neutral, and alkaline solutions, is offered as an

explanation of the fact that the plant does not absorb phosphates in solutions of high pH or of very low pH. It shows that optimum absorption should occur at the iso-electric point, which varies slightly from plant to plant. A diagram is presented which shows the cycle of possible changes which soil phosphates undergo as a result of pH changes and explains how carbon dioxide and its ions may render phosphates soluble or insoluble according to the proportion of these constituents present in solution.

A lysimeter study of the nitrogen balance in irrigated arid soils (No. 169 P). For many years it has been known that a radical difference exists in the nitrogen balance of cultivated soils under humid and under arid conditions which cannot be explained solely on the basis of the nitrogen removed in the crops or lost in the drainage. Continuous cropping to non-legumes in humid regions *rapidly* depletes the nitrogen supply in the soil, but under arid conditions even after many years of continuous cropping to non-legume crops, fair yields are still obtained and there is no appreciable decrease in the originally low nitrogen content of the soil. In certain instances gains in the nitrogen content have been reported. This may be due to progressive bacterial, nonsymbiotic fixation of atmospheric nitrogen or to the utilization by the plants of available nitrogen from the lower soil strata with subsequent deposition as straw or other plant refuse in the surface root.

All previous work done on the subject of nitrogen balance in arid soils has been performed by analyzing field samples from a virgin, uncropped soil and a nearby cropped soil of the same type or from plot tests where no attempt was made to control conditions to the extent of determining the nitrogen lost by cropping or by drainage.

It seemed advisable to study the nitrogen balance of at least two important soil types in Arizona under conditions which could be rigidly controlled. A series of 12 soil tanks, 4 ft. \times 4 ft. \times 5 ft., were available for the work, so six were filled with weighed amounts of Gila clay loam and the remainder with Mohave clay, two important soil types in Arizona. Physical, chemical, and bacteriological analyses were made of the two soils. A 5-year rotation was planned and started after the first year, during which a wheat crop was grown to determine the uniformity of the soils. The rotation is as follows:

- 1st. year, Cotton
- 2nd. year, Hegari and wheat
- 3rd. year, Wheat and alfalfa
- 4th. year, Alfalfa
- 5th. year, Alfalfa

One tank of each soil was left out of the rotation and is planted continuously to wheat and hegari each year. The tanks are irrigated with known amounts of water and if there is any drainage it is caught and poured back on the soil. There is thus no chance for a mechanical loss of nitrogen by leaching. Crops are removed, weighed, and analyzed for nitrogen. The rain water from a nearby gage is analyzed to determine the amount of nitrogen brought to the surface by rains. The first wheat crop was planted in November, 1930, and the regular rotation started the following spring. Periodic analyses of the soils are to be made during the 20 years or more the project is to run to determine any changes in their nitrogen content due to cropping.

Weather observations at the University of Arizona (No. 160 S). In 1875 systematic observations of the weather were begun at Fort Lowell. A few years later the station was moved to the corner of Main and Congress streets, Tucson. In 1891 the station was transferred to the University Campus and since that time the responsibility of making the observations and compiling the data has been with the Department of Agricultural Chemistry and Soils.

In 1928 the observation of the weather became a state research project, and Bulletin 130, which is a summary of the climatology of the State, was published in April, 1930. The accompanying table gives the weather statistics for the past calendar year at Tucson.

Cooperative projects. A considerable portion of H. V. Smith's time during the year was spent making fluoride determinations in cooperation with the Department of Human Nutrition on their project No. 168 P. As part of his work, a survey of the public water supplies of the State has been made and 200 samples of water analyzed for fluorides. This work will be published as a Technical Bulletin from this Station.

Miscellaneous studies. From time to time short research problems arise which are not of sufficient importance to warrant the drawing up of a formal project. For example, the determination of the chemical characteristics of certain desert plants may be cited as a case in point. During the past year several such short studies were conducted. These include investigations on the fiber and waste of *Agave lechuguilla*, the pulp and seeds of *Adansonia digitata* (Baoba Tree), the beans of *Parinsonia aculeata* (palo verde), and the wax and seeds of *Simmondsia californica*. The effect of burrowing rodents upon the physical and chemical properties of soils of grazing ranges has also been given some attention. The kangaroo rat and pack rat produce significant physical and chemical changes in soils and these changes are probably more beneficial than injurious over a long period of time. Several papers have been published dealing with these subjects and these are given in the list of publications from this Department.

AGRICULTURAL ENGINEERING

G. E. P. SMITH

Groundwater studies (No. 1 A and S). Groundwater storage supplies have been increased to a large extent by the greater than average precipitation of 1931, which was preceded by a year of almost average rainfall. Groundwater supplies have also been somewhat augmented by the diminished pumping draught due to the depression in prices of agricultural commodities, which has resulted in a smaller irrigated area. Drouth conditions had prevailed for the 6-year period previous to 1930, during which the water level in many pumping districts was reduced to the lowest level ever recorded. Rainfall records in southern Arizona indicate that this drouth, extending over a period of 6 years, was as severe as any which has occurred during the past 50 or 60 years, for which rainfall records are available.

Groundwater supplies in the Rillito Valley, which are replenished principally by seepage from flood flows in the Rillito River, fluctuate through a wide range depending upon rainfall and resulting runoff in the river. This fluctuation in water supply is shown in Figure 1 by the variation in water level for the period 1918-1932 at the University Farm well. As shown in Figure 1, a maximum variation of 17 feet in water level occurs. At this particular well good water-bearing material extends only to the depth of 36 feet. The capacity of the well is therefore seriously affected by the wide fluctuation in water level. The specific capacity of the well with the water level at 8 feet is approximately 60 gallons per minute per foot of drawdown, whereas, when the water level is at 24 feet the specific capacity is reduced to 20 gallons per minute per foot of drawdown. Storage capacity in the case of groundwater reservoirs thus becomes a factor of importance equal to that in the case of surface water reservoirs.

Studies have been continued upon the old Pima Farms Company Project. Water levels have been taken upon some 60 or 70 wells in and adjacent to the pumping district. The pump discharges have been measured and the daily discharge of each pump computed from the pumping records of the company. A continuous water level recorder has been maintained upon one of the wells in the lower end of the pumping area since 1922. This record serves as a key in the interpretation of what has occurred in the entire lower half of the area.

Recharge to the area occurs mainly in the form of underflow down the Santa Cruz Valley, the Rillito Valley, and Canada del Oro, and by

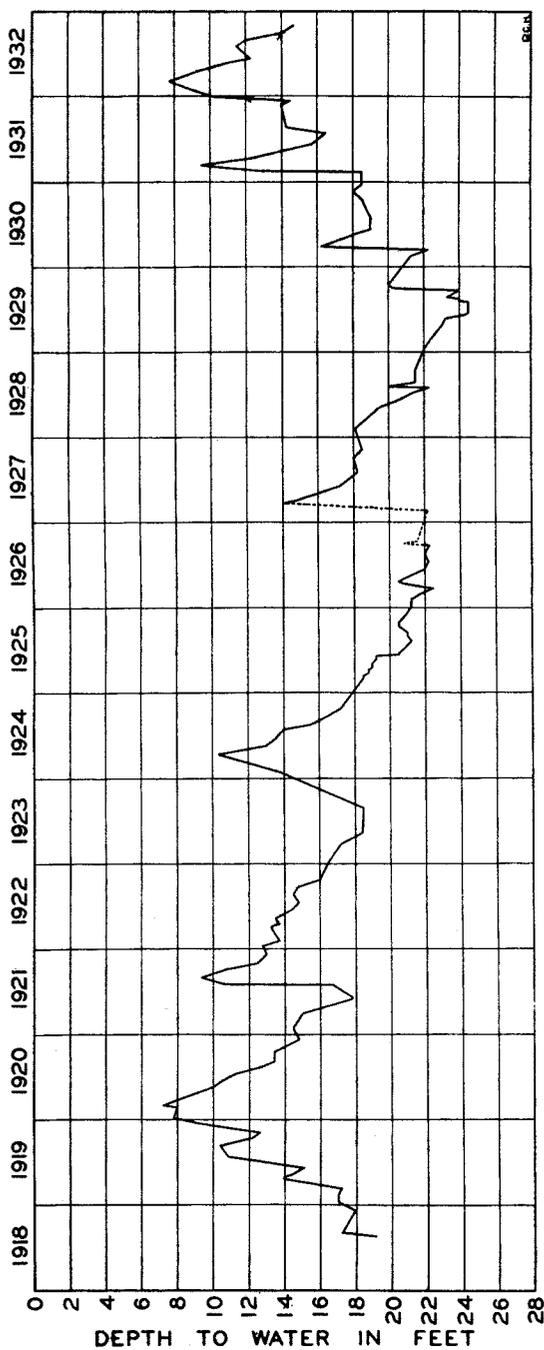


Fig. 1.—Fluctuations of the water table at the University Farm, 4 miles north of Tucson. High water table follows periods of much rainfall and flood flows in the Rillito River. The “recharge” of the groundwater supply in summer of 1921 is noteworthy, but in general the important recharge periods follow winter floods.

seepage losses from flood flows in the Santa Cruz River. Chemical analyses of the well waters show that the salt content of the underflow varies, depending upon its source. It appears that little mixing or diffusion occurs in groundwater flow and that the variation in salt content of the water throughout the district may serve as an indication as to its source. In one case two wells within 1,200 feet of each other, which have been pumped heavily for a period of over 10 years, have shown consistently a total salt content, in one of less than 200 parts per million as compared with over 400 parts per million in the other.

The drilling of several new wells near the boundaries of the pumping district has made possible the extension of groundwater contours with greater certainty beyond the project limits. The groundwater contours indicate the direction of flow and it is hoped that, in conjunction with chemical analyses of pumped water, the relative amount of water derived from each of the three principal sources of underground water may be determined.

Interference tests were made on pumping plants 16C₁ and 16C₃ which are only 770 feet apart. Contrary to expectations the interference was negligible, the ratio of the discharge with interference to that without interference being 0.96 in one case and 0.97 in the other.

The cost of irrigation water from wells was determined for six typical equipped plants equipped with deep-well turbine pumps and electric motors. The total cost of water for 1930 was computed, taking into consideration fixed charges, operation and maintenance, and power costs. Financing in this particular area was mainly through a cotton brokerage and seed firm which made a direct charge of only 6 percent for interest. Interest was therefore charged at only 6 percent per year. The allowance for depreciation was made high enough to include repairs and maintenance and was figured as follows: Pumps at 11 percent per year, electrical equipment at 7 percent per year, and wells at 3 percent per year. The average price paid for power on the low-tension side of the transformers was about 1.87 cents per kilowatt hour. Water costs were found to vary from 3.2 cents per acre-foot per foot of lift to 3.9 cents per acre-foot per foot of lift. This variation is due to some extent to differences in efficiency of equipment but mainly to a difference in the ratio of fixed charges to operating costs. This ratio varied approximately from 0.45 to 1.10. The actual costs of water varied from \$4.00 to \$9.00 per acre-foot.

Pumping Machinery (No. 2 A and S). Although this project has been upon the inactive list for the past year, opportunity was presented for securing some comparative data on the effect of length of service upon the efficiency of deep-well turbine pumps.

Efficiency tests were made upon six representative plants in the Casa Grande Valley which had been in service between two and three seasons. Pump capacities ranged from 3.02 second-feet to 4.87 second-feet with total lifts varying from 65 feet to 118 feet. The resulting pump efficiencies varied from 58 percent to 70 percent with an average of 65 percent for the group.

Similar tests were made on 13 plants of the Cortaro Water Company located on the lands of the old Pima Farms Company. These plants, which had been in service 5 or 6 years, were operating under total heads of 62 feet to 94 feet and had pump capacities of between 2.50 second-feet and 3.30 second-feet. Pump efficiencies were found to vary from 55 percent to 68 percent with an average for the group of 62 percent.

The above results indicate that, when pumping clear water and with proper maintenance, very little lowering in efficiency should be expected in 5 or 6 years of service with the deep-well turbine type of pump. The average difference of 3 percent between the efficiency of the two groups cannot be attributed entirely to the difference in length of service. It may be due in part to some slight improvements in design in the newer pumps and also to the fact that the pumps in the group having the higher efficiency were of somewhat greater capacity.

Evaporation and duty of water (No. 32 A). The operation of three class-A evaporation stations, located at Willcox, Mesa, and Yuma, Arizona, has been continued. During the past year a slight change was necessary in the location of the Willcox station but its exposure has not been affected. Records from these three stations are now available from 1917 to date and become more valuable as the length of record is increased. Long-term records are necessary for the proper interpretation and use of results of all duty-of-water experiments.

Citrus irrigation investigations (No. 129 P). These studies are conducted on the Yuma Mesa jointly with the Department of Horticulture. They were initiated in January, 1927, and for the most part have dealt with young grapefruit trees planted that year.

The results of the first 4 years were published in Technical Bulletin No. 37, on December 15, 1931. The sections of the bulletin prepared by this department deal with climate, soil, soil-moisture determinations, downward movement of moisture and water-holding capacity, uniformity of distribution and its relation to slope, consumptive use of soil moisture by trees, irrigation practice, variation of soil temperature and its factors, the effect of irrigation on soil temperature, and alternative methods of controlling soil temperature.

During the past year the field work has included the continuation of

complete irrigation and soil-moisture records of the 18 plots of the citrus tract, each plot consisting of 52 trees, for correlation with tree development. Soil samples are taken before and after each irrigation to a depth of 6 feet. It is found that development depends on frequency of irrigation, rather than on quantity applied, so that the study is made to apply a small quantity and yet obtain uniform distribution throughout the length of the row. Soil temperature records for various depths within the soil are being continued on each of the six plots of Block II and on the nearby desert. The temperatures are much influenced by frequency of irrigation but there is little difference in this respect as between frequencies of more than 2 weeks.

Four new plots of 39 trees each on adjoining ground were set out March 7, 1932. They will be used to test alternative methods of soil-temperature control, the need of which extends from about June 20 to September 15 and is most acute for young orchards, as follows:

Plot 1—Weekly irrigations during the period of high soil temperature.

Plot 2—Control by means of cover crop of alfalfa planted in March.

Plot 3—Control by means of covering of dry straw 6 feet in diameter around each tree.

Plot 4—Control by means of cover crop of cowpeas planted May 31 and it was expected the young plants would furnish effective shade by the end of June.

Good stands, both of alfalfa and cowpeas were secured. If there are indications that the cover crops are depriving the young trees of an adequate supply of nitrogen, sodium nitrate will be applied with each irrigation. The soil temperatures at 1 foot depth on June 28, at 10 a.m. varied from 91.8° F. on Plot 1 to 86.0° on Plot 3.*

The desert soil temperature at 2 feet depth was 90.4°. In a Plot 2 of the 1927 planting the temperature was 90.8 midway between trees, and 87.3 in the shade of one of the trees.

Special tests of evaporation losses were made by slicing 2-inch layers of the top foot and testing separately. The data show that on January 18 the effect of evaporation was confined to the upper 2 inches; on April 4 the depletion of soil moisture was very little except in the upper 3 inches; on May 16, 6 weeks after irrigation, the effect was confined to the upper 5 inches, while below 5 inches the moisture was at the moisture-equivalent point, which is approximately the field water-holding point. The evaporation loss is much less than has been commonly believed. There is no evidence in these tests of upward capillary movement. It appears that the loss is due to the taking in and expulsion of

*The respective temperatures on the four plots on September 20 at 10 p.m. were 90.4, 86.2, 87.4, and 83° F.

air due to variations in barometer pressure, especially the normal diurnal changes.

Special studies of downward movement of soil moisture and field water-holding capacity have been made in small, bare plots, heavily irrigated at the outset. To a depth of 6 feet in both winter and summer, the moisture percentage, after the first week, continues to decrease slowly for at last 8 weeks, somewhat faster in the summer. It may be that in summer part of the loss is due to the diurnal vertical oscillation of the soil air which probably averages 3 inches or less, but most of the loss is due to a slow movement downward of the moisture. It is difficult therefore to define water-holding capacity except as an approximate condition. Also, the time of taking after-irrigation soil samples is important and should be stated in a report; for the Yuma Mesa it is considered best to do the sampling 2 days after the irrigation.

Comparisons between downward movement in winter, spring, and summer are being made, placing the successive sampling points as the first points of the three series, in the form of small triangles so that the effect of soil texture is entirely eliminated. Moisture studies might be done more easily in the laboratory, but the soil structure is then in an artificial condition and the action of long capillary tubes is lacking and the results might be misleading.

One basin 11 feet square was prepared on undisturbed desert soil, and water to which $\frac{1}{4}$ pound of sodium nitrate had been added, was applied to a depth of 10 inches. Soil samples were taken 24 and 48 hours later and the nitrates were determined. The highest concentrations were found below 7 feet depth. The purpose was to demonstrate experimentally that heavy irrigations do positively carry nitrates downward below the root zone, and for that reason it is wasteful to apply at one time more water than is necessary to restore the moisture content in the upper 3 or 4 feet.

In an effort to find a quick method of obtaining the permanent wilting percentages of soils adapted to use in the field, a study was made of correlations between mechanical analyses, moisture equivalents by centrifuge, and wilting percentage by pot tests, using 20 selected samples from the Yuma Mesa. The moisture-equivalent: wilting-point ratios varied from 1.7 to 3.0 and averaged 2.25. Correlations between wilting point and clay and between wilting point and total silt and clay were good but some further trials are needed to establish curves for field use. Such curves may prove to be impractical for the surface soil because of variable humus content, but it is believed they will be reliable for the root zone which extends from the depth of cultivation to 5 or 6 feet, and determines the frequency of irrigation.

Some additional data on effect of slope on distribution and duty of water were obtained. Two orchards on the Mesa, both of which made excellent growth in 1931, were given heavier irrigations than was necessary, but on one of the two the irrigations averaged 57 percent heavier than on the other. The latter was found to have a fall of 3 inches lengthwise of the row, while the former was level. The evidence is that, for rows 330 feet long, the usual length, the fall should be from 2 to 4 inches.

Consumptive-use studies were conducted on two plots, one irrigated every 3 weeks and one every 4 weeks through the summer, and at longer intervals in spring and fall. The trees on the latter plot were the larger. As an illustration of the comparison, the consumptive use by the larger trees in the early part of July was at the rate of 0.10 inch depth of water per day, and the use by the smaller trees was 0.08 inch per day. On both plots the highest rate of use was in May.

A number of tests were made for comparison of transpiration from shaded and sunny sides of a tree.

Miscellaneous. The irrigation engineer served as secretary and prepared the report for the land and water committee of the Yuma County Economic Survey. He served also as member of the advisory committee of the American Engineering Council to report on proposed legislation affecting the disposal of the remaining public lands of the United States, and has been appointed member of committee on reclamation, irrigation, and drainage policies of the national land-use planning committee.

At the request of the secretary of the Yuma County Water Users' Association, a report on proposed drainage extensions in the Yuma Valley was analyzed. Numerous mistakes were found in it. The report purported to show that the cost of drainage by pumping was exorbitant, but with the mistakes corrected, it appears that it may be feasible to drain some remaining undrained portions of the Valley by this method.

The associate irrigation engineer was granted a 2-weeks leave to assist the Rockefeller Foundation, Division of Medical Research, and the State Health Department of Alabama, in a consulting capacity. The work consisted in the interpretation of the results of groundwater pollution studies and a layout of plans for future studies in the field near Andalusia, Alabama.

At the request of the United States Forest Service, assistance was given in the problem of providing water supply for the numerous camp sites in White House Canyon, the only supply available for the dry months being a meager groundwater seep.

With the cooperation of the Flowing Wells Irrigation District, a

concrete weir box with steel crest was built on the Flowing Wells canal and a Stevens water-stage recorder was installed over a stilling well. The resulting data will serve as a basis later in the study of the water supply and duty of water on this project.

Frequent additions are made to the volume of data on wells and groundwaters throughout the State, and it is expected that ultimately a groundwater survey of the State can be accomplished.

AGRONOMY

R. S. HAWKINS AND IAN A. BRIGGS

There follows a summary of progress made during the past fiscal year on active projects in the Department of Agronomy.

Cotton production and soil and climatic environment (No. 113 P). Particular emphasis has been placed upon the relationship between the supplies of plant food in the plants as indicated by certain plant properties and the abscission of the young bolls. Factors affecting flowering and the maturity of the bolls have also received some attention.

The plants were grown in field plots and the soil moisture was regulated by means of a concrete pipe irrigation system. Soil-moisture conditions were determined weekly from soil samples taken with a soil tube to the depth of 5 feet. The fruiting behavior of the plants was ascertained by the daily tagging of the flowers on 20 representative plants on each plot. Shedding and boll maturity data were also recorded on the tags.

The physiological conditions included in the investigation, in addition to the fruiting behavior, were the osmotic pressure, the specific conductivity of the expressed leaf sap, and the carbohydrate and nitrogen conditions in the stems. The modifications in internal structure, as influenced by the various physiological aspects and by the soil moisture, was investigated by means of cross-sections of the stems.

While the osmotic pressure of the leaf sap, the specific conductivity of this cell fluid, and the carbohydrate content were usually correlated with the available soil moisture, other factors exerted a greater influence at times. Humidity and temperature changes occasionally appeared to effect changes in these properties of more import than soil moisture influences. However, soil moisture through its relation to the nutrition of the plant is a major factor in the regulation of fruiting.

High osmotic pressure, specific conductivity, and carbohydrate content, when accompanied by moderate plant growth, were also followed by low shedding. Evidently under these conditions, sufficient plant food was present to provide for moderate plant growth and also for the needs of most of the flowers and bolls. Conversely, when these properties were low; rapid growth was stimulated, and high boll-shedding was induced, because of insufficient food supplies for both the excess vegetative growth and also for fruiting purposes. Extremely high osmotic pressures and specific conductivities of the leaf sap and high carbohydrate content of the stems, when induced by severe deficits of soil moisture, were followed by intense shedding. Microscopical exam-

inations of cross-sections of the stems, collected during such extreme conditions, indicated that the cambium was very inactive and the last cells produced were small and thick walled. The inactivity of the cambium, the thickening of the cell walls, and the high carbohydrate content would indicate that even though the supply of plant food were high, it was used to build thick walls in cells already formed, and for storage purposes. As a consequence the amount of readily available food for the promotion of growth in the rapidly developing young bolls was too limited and abscission ensued.

The activity of the cambium in the stems of the cotton plants was directly correlated with the supply of available soil moisture. The withholding of water for 8 weeks eliminated all visible evidences of cambial activity. At that time the soil moisture supplies were below the wilting coefficient in all but the fifth foot of the root zone. Growth, following the addition of irrigation water, was seemingly as extensive in the plants which had gone through a severe period of water deficit, as in those which had not experienced water shortage.

The xylem was much more abundant in the stems of plants which had been adequately supplied with water than in those with limited moisture. The amount of phloem was also greater in the plants which experienced no water deficit though these differences were not as great as in the xylem. The other tissues, cortex and pith, farther removed from the cambium, were not influenced to any appreciable extent by the soil moisture differences which prevailed in this investigation.

The activity of the cambium was correlated, in a general way, with the abscission of the young bolls. Rapid vegetative growth, as expressed through the formation of large, thin-walled cells in the secondary tissues of the stems, was accompanied by a high percentage of shedding. Likewise, when the cambium was exceptionally inactive, intense shedding occurred. An intermediate condition of cambial activity favored the retention of the bolls.

Thus the interrelation of the osmotic pressure and specific conductivity of the leaf sap, and the carbohydrate content of the stems, and the close correlation of these three properties with boll-shedding, furnishes further evidence that the percentage of shedding is regulated by the amount of plant food available for the development of the young bolls.

Time of cutting alfalfa (No. 128 P). This work has been continued during the past year on the plots started in January, 1930. As during the first year of the test, no appreciable differences were noted between the Common and Hairy Peruvian varieties. Yield data in pounds per acre for the various stages of cutting were as follows:

Variety	Bud	Stage of cutting	
		One-third bloom	Full bloom
Hairy Peruvian	14,072 lbs.	14,767 lbs.	14,767 lbs.
Common	13,906 lbs.	15,517 lbs.	14,388 lbs.

Considerable encroachment of grasses, chiefly Bermuda, has occurred on all the plots cut in the bud stage. Good farming practice would dictate a change of crops on these plots but all plots will be carried throughout the present season. Part of the trouble from the grass was brought about because the border ridges could not be properly seeded a falling off in the stand as seems apparent. Counts made on six

Stand counts conducted in January, 1932, did not indicate as marked to alfalfa.

1-meter-square areas on each plot, two near each end and two near the center, gave results as follows:

Variety	Bud	Stage of cutting	
		One-third bloom	Full bloom
Hairy Peruvian	80	87	88
Common	118	101	115
Average	99	94	102

Wheat varieties for northern Arizona (No. 122 S). This wheat variety test has been continued for the past 5 years at Eagar, Arizona, at an elevation of 7,000 feet. The data are being assembled for publication. The results for the 5-year period indicate the desirability of the Defiance and Marquis varieties for this section of the State.

The project is being discontinued. It is felt that the small-grain nursery work carried on cooperatively at the same place by the Arizona Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, will best meet the needs of the community. The cooperative work will include plantings of barley and oat varieties as well as wheat varieties for rust-resistant strains.

The average acre yields for the 1931 crop were as follows:

	<i>Bushels</i>
Defiance	22.6
Federation	17.8
Dicklow	17.4
Marquis	17.3
Early Baart	17.3
Hard Baart	16.5
Bluestem	15.6

Culture and development of Pima and Upland Cotton (No. 62 S). The experimental work in connection with this project was divided into three phases: (1) Border effect, (2) Width of rows, and (3) Varieties.

To determine the border effect, Acala cotton was planted in 2-, 3-, 4-, and 8-row plots, with four replications. Acre yields of seed cotton were as follows:

2 row plots.....	1589 lbs.
3 row plots.....	1541 lbs.
4 row plots.....	1627 lbs.
8 row plots.....	1442 lbs.

Row spacings of 3½, 4, and 5 feet were used in the spacing test. Resultant yields were 1,927 pounds, 1,929 pounds, and 1,686 pounds respectively for the spacings indicated.

Mebane gave the highest yields in the cotton variety test followed in order by Acala, Lone Star, and Pima.

Study of small grain crops (No. 64 S). Variety tests with the small grains are being carried on at the Salt River Valley Experiment Farm at Mesa in cooperation with the Office of Cereal Crop Investigations, United States Department of Agriculture. Work with the small grains also includes detailed studies of irrigation and border effects on small plots.

Variety test plots harvested in the summer of 1931 indicated Early Baart as the leading wheat variety with several other varieties yielding nearly the same. The barley variety test resulted as follows:

Trebi	4,116 pounds threshed grain per acre
Sacramento	3,827 pounds threshed grain per acre
Common Six-Row	3,382 pounds threshed grain per acre
Beardless	3,243 pounds threshed grain per acre
Club Mariout	3,230 pounds threshed grain per acre

Culture and improvement of legumes (No. 65 S). An extensive date-of-planting test with Whippoorwill cowpeas and sesbania indicated that the cowpeas were superior as a green-manure crop for late or mid-summer plantings while the earlier plantings gave higher yields for the sesbania. The advantage of early planting of sesbania was particularly marked in the seed yields obtained which were as follows:

<i>Date of planting</i>	<i>Seed yield per acre</i>
June 16	1,533 pounds
July 1	1,038 pounds
July 14	732 pounds

Early Baart wheat is being grown now on the sesbania and cowpea plots to further check the value of these crops for green manure purposes. Yields last season showed an average of 2,296 pounds of wheat following sesbania as compared with 2,588 pounds following cowpeas.

Cooperative field experiments (No. 17 S). Two experimental tests were carried under this project during the past year. These were a soil-preparation and seedbed experiment in Chino Valley, Yavapai County, under the direction of County Agent E. S. Turville and a cotton-variety test at Duncan, Greenlee County, under the direction of County Agent K. A. Boevers.

Beginning with the spring of 1932, the work was increased to include variety tests of cotton at Duncan, Yuma, Coolidge, and Casa Grande, and corn variety tests in Cochise and Coconino counties. The varieties of cotton included in some or all of the tests were Mebane, Stoneville 1-4, Delfos 531, Delfos 719, Pima 5-3, Paris Big Boll, Atwood Kasch, Oklahoma Triumph 44, and several locally grown and introduced strains of Acala. Among the varieties of corn in the various tests were Minnesota 13, Big Golden Glow, Golden Republic, Reid's Yellow Dent, Arizona strains of Duncan White Dent, Duncan Yellow Dent, Creidebring's Yellow Dent, Newberry's Mexican June, and several local strains not named.

Cost of producing field crops in Arizona (No. 133 P). Work on this project has not been continued since the resignation of Mr. S. P. Clark in October, 1931, except for the compilation of the data previously collected. Summaries of these data are now in the hands of Mr. Clark who is assembling them for publication.

The average costs per acre and per unit produced for a few of the crops included in 1930 are as follows:

<i>Crop</i>	<i>Acre yield</i>	<i>Acre return</i>	<i>Cost per unit</i>	<i>Selling price per unit</i>
Alfalfa hay	4.23 tons	\$56.11*	\$12.47	\$12.41
Barley	21.03 cwt.	28.40	2.14	1.35
Hegari grain	24.45 cwt.	28.12	1.76	1.15
Hegari silage	13.5 tons	54.00	3.68	4.00

The following publications were issued by the Department during the year:

"Methods of Estimating Cotton Fiber Maturity," by R. S. Hawkins, was published in the *Journal of Agricultural Research*, Volume 43,

*Includes \$3.65 from pasture sales.

October 15, 1931, pp. 733-742. This study deals with the methods of determining fiber maturity and with the various factors which affect such maturity. It was found that the fluffiness of the boll is indicative of the maturity of the fibers as were also the color, plumpness, and maturity of the acid-delinted seed. High concentrations of soil alkali, a comparatively low supply of soil moisture, and early frosts are contributing factors in the production of high percentages of immature fibers. Varietal differences are common. The largest amount of immature fibers is usually found in the last picking.

"Cost of Producing Field Crops in the Salt River Valley, Arizona, 1928," Arizona Station Bulletin No. 139, by S. P. Clark was issued October 1, 1931. This publication deals with the production costs on a representative group of farms in the Salt River Valley devoted to the production of Pima and short staple cotton, alfalfa, and wheat. A summary of the costs including interest charges gave the following acre and unit costs for the four crops:

<i>Cost per acre</i>	<i>Cost per unit</i>
Pima cotton.....\$87.59	Pima, pound.....\$0.233
Short staple..... 62.70	Short staple, pound..... .127
Wheat..... 35.23	Wheat, 100 pounds..... 2.03
Alfalfa..... 49.07	Alfalfa, ton.....13.17

Costs for cotton are the total costs less credit for seed produced. The average yields per acre for the four crops on the 36 farms included in the study were: Pima cotton lint, 379.5 pounds; short staple cotton lint, 495 pounds; alfalfa, 3.92 tons (not including the amounts pastured off); and wheat, 1,903 pounds.

ANIMAL HUSBANDRY

E. B. STANLEY* AND E. L. SCOTT

The Animal Husbandry research and instructional equipment has been materially improved during the year. The machinery shed at the Salt River Valley Experiment Farm has been extended to cover four feed-storage bins and to provide a roof over the scales and other feed-weighing equipment. Two additional units have been added to the steer-feeding pens. A recent policy established at the Experiment Station should facilitate greatly the improvement of our herds and flocks. This ruling makes it possible for a limited amount of the proceeds from the sale of stock from the University Farm to be used in the purchase of registered breeding stock.

The University Hereford herd has been improved by the addition of two bulls and five heifers. Mousel Domino Mischief is being held in reserve to the herd sire, Bocaldo 51st. Mr. Floyd Kimble of Douglas, Arizona, has recently presented the University with a prospective herd sire. This bull calf was sired by Superior Prince Domino 1st., and out of a Domiana cow. The five females added to the herd are of Anxiety 4th breeding and were secured from the Wyoming Hereford Ranch, Ken Caryl Ranch Company, and Mousel Brothers.

The swine herds at the University Farm have been strengthened by the addition of a Poland China herd sire, Good Knight, a son of the Grand Champion Poland boar, Good News. Three Poland gilts sired by the many-times champion boar, Silver Star, and a junior boar pig sired by Fashion Heir, 1931 International Grand Champion, have also been placed in the herd. Four Duroc gilts and a boar pig, all sired by Revelite's Advance, Grand Champion Duroc boar at three of the big Midwestern shows in 1931, and out of a daughter of Leader Lassie, undefeated World Champion sow, have been acquired for the purpose of strengthening the University Duroc herd.

The Hampshire flock has been reinforced by a ram and six ewes. The ram is sired by an imported English Flower-bred ram, Chilmark Perfection. The ewes came from the Thousand Springs Hampshire flock and were sired by the English ram, Blendworth Basildon. The ram and one of the ewes were made Grand Champion Hampshire Ram and Ewe respectively of the Arizona State Fair, 1931.

Range livestock losses from poisonous plants (No. 171 P). Work on this project was concentrated on an investigation of the causes of cattle death losses in the limestone hills area of southern Arizona. The project

*On sabbatical leave 1931-32.

was undertaken in cooperation with Messrs. Boice and Hilton, ranchmen in the limestone area.

Two separate typical loss-areas were selected, fenced, and mapped as to topography and plant growth. Cattle were placed within the areas and were under constant observation. Temperatures were recorded by means of a thermograph. All plants on the area were tested for cyanogenic glucosides and the tests were repeated at regular intervals. The following plants reacted positive to the test and are listed in the order of the intensity of the reaction: *Acacia sp.*, *Leptochloa dubia*, *Mortonia scabrella*, and *Rhus sp.*

Death losses were incurred at the inception of low temperatures and the victims showed an accumulation of hydrocyanic acid or of hydrocyanic-acid-forming compounds in the brain tissue. The evidence to date points rather directly to hydrocyanic acid, and to the acacia plant as the probable cause of the losses. Additional work will be necessary before the cause of the losses can be definitely determined.

Several special trips were made by the investigators in response to reports of poison-plant losses being incurred by ranchmen. The losses were determined to have been caused by nutritional disturbances, either malnutrition or digestive derangements due to the consumption of unsuitable types of forage as a result of abnormal or depraved appetite. In some instances infectious diseases were indicated and later the prognosis verified by microscopic examination or by the diagnosis of an animal pathologist. In none of the cases studied were poisonous plants indicated.

A study of the foraging habits of range cattle (No. 172 P). This project was approved along with the project on livestock losses and some preliminary observations and data were accumulated as a result of studies in connection with the livestock losses project. Daily observations were made on the activities and foraging habits of the cattle kept in poison-plant areas. Palatability estimates were recorded along with notes on the grazing habits, condition of the plant growth, temperatures, etc. This is a long-time type of project and it is planned to accumulate data on the subject by direct observations, by palatability and utilization studies, and in conjunction with the investigations in the "livestock losses" and in the "deficiencies of range forages" projects.

Steer feeding experiment—Salt River Valley Experiment Farm (No. 140 S). One hundred yearling steers were allotted and fed experimental rations at the Salt River Valley Experiment Farm from November 29, 1931 to March 27 and April 26, 1932. From the data secured on the

comparisons included in the experiment the following deductions were made:

1. When fed with a basal ration of hegari silage and cottonseed meal—a ration in which a surplus of protein is furnished by the meal—the higher grades of hay were found to pay the extra cost of the hay and return a slight margin besides.

2. The results secured would indicate that, when fed under the conditions of this experiment, ground hay had no higher feeding value, pound for pound, than did the corresponding long hay.

3. Alfalfa-barley hay in the proportion of 3 parts of No. 2 alfalfa hay to 1 part of good barley hay, when fed in addition to the basal ration of silage and meal, gave results that were equally as good as those shown by straight alfalfa.

4. Barley-alfalfa hay in the proportion of 3 parts barley and 1 part alfalfa, fed in addition to the basal ration, was not as efficient in producing gains as either alfalfa hay or alfalfa-barley hay. The steers in lot 8, the barley-alfalfa hay-fed group, made the lowest daily gain, showed the highest feed cost per hundredweight of gain and required the greatest margin per hundredweight of any of the lots in the experiment. The steers did not relish the barley-alfalfa hay.

5. In last year's feeding experiment the steers fed only silage and meal made slightly more efficient gains than did the steers fed hay, silage, and meal. This year the results are slightly in favor of the hay-silage-and-meal ration over the silage-and-meal ration alone. On the basis of the two trials it would seem that these two rations are approximately equal in the efficiency of producing gains.

6. Ground hegari fodder proved to be a suitable feed for the steer fattening ration when fed with cottonseed meal. The steers in the fodder-fed group made the highest average daily gain of any of the lot of steers. On the basis of the unit of dry matter consumed, the gains produced by ground hegari fodder were approximately equal to those produced by the corresponding silage. Since the cost of ground hegari fodder is not definitely determined and since it is not a market product, no cost figures for this feed are presented at this time.

7. The average feed cost per hundredweight of grain increased each 30 days during the experiment. These average costs ran consecutively, \$4.92, \$5.85, \$6.11, and \$9.23 per hundredweight of gain.

8. Thirty-four head of "hold-over," unfinished steers, fed an additional 30 days on a daily ration of 5.91 lbs. hay, 23.90 lbs. of silage, 3.72 lbs. meal and 1.75 lbs. rolled barley, made an average daily gain of 2.04 lbs. per head at a feed cost of \$6.15 per hundredweight of gain.

Lamb feeding experiment—Salt River Valley Experiment Farm (No. 139 S). During the period beginning November 29, 1931 and ending February 27, 1932 the Animal Husbandry Department fed 160 lambs, divided into eight groups of 20 lambs each, on experimental rations.

The summarized results are given in tabular form in a published report. They appear to justify the following conclusions, but it should be remembered that only one feeding trial has been conducted using these comparisons.

1. No. 3 alfalfa hay produced slightly more economical gains than did the better grades of alfalfa hay when fed with a basal ration of hegari silage and cottonseed meal. A surplus quantity of protein was furnished by cottonseed meal.

2. The results secured would indicate that when fed under the conditions of this experiment, ground hay had a higher feeding value, pound for pound, than did the corresponding long hay. In each of the three direct comparisons the lambs receiving ground hay required less feed per hundredweight of gain than did those fed baled hay.

Ground hay in the ration increased the efficiency of the ration approximately 9 percent. In these rations 393 pounds of hay were required per hundredweight of gain. If the difference in efficiency be attributed to the grinding of the hay the value of the ground hay used in this experiment was \$2.79 per ton more than that of the baled hay. This figure would vary with the price of hay.

3. Neither the alfalfa-barley nor the barley-alfalfa hay was as efficient in producing gains as alfalfa hay when fed to lambs in addition to the basal ration. The lambs made satisfactory gains and the results would indicate that when these hays are relatively cheap they may be used to advantage in the lamb fattening ration.

4. One-half of the lambs in each lot, a total of 80 head, were sheared at the beginning of the experiment. The 80 sheared lambs gained a total of 1,941 pounds during the 90-day period as compared to a gain of 1,888 pounds made by the unsheared lambs. The difference in the average daily gain per head was only 0.01 pound in favor of the sheared lambs.

5. Inclement weather encountered during the feeding period resulted in the loss of three sheared and one unshorned lamb.

Harvesting hegari stalks by the use of steers. The feeding trial was conducted for the purpose of testing the feasibility of pasturing headed hegari stalks with beef steers.

Forty head of 1- and 2-year-old Hereford steers were pastured on successive areas of headed hegari stalks supplemented with cottonseed meal fed in troughs in the field twice daily. The steers were turned into the field November 11, 1931 and were removed to the finishing pens on December 15, after the stalks had been grazed down to where the plow could turn them under readily. During the 45 days while the steers were on stalk pasture they were fed 3 pounds of cottonseed meal per head daily. When the last area of stalks was grazed until it furnished insufficient feed for the steers, the daily ration was supplemented with a small amount of hegari grain and enough silage to get the steers accustomed to the dry-lot ration. Twenty acres of hegari stalks furnished forage for 40 head of 759-pound steers for 46 days.

On December 15 the steers were placed in the dry lot and given a daily ration consisting of 6 pounds of ground hegari grain, 4 pounds of cottonseed meal and all of the hegari silage they would eat. They were marketed locally as they reached a market finish.

These feeder steers weighed 30,355 pounds net at Amado, the loading station. They were on the experimental ration 2,910 steer-days and they weighed 35,028 net at the slaughter plant. The average daily gain per steer was 1.6 pounds.

The steers cost \$1,419 at the farm, they consumed 5.15 tons of cottonseed meal, 3.3 tons of ground hegari, $\frac{1}{2}$ ton of alfalfa hay, 20 tons of hegari silage and 350 pounds of salt at a total feed cost of \$307.65 making the investment in cattle and feed \$1,726.65. They sold for \$2,276.00 leaving \$549.35 to pay for labor, hegari stalks, and minor miscellaneous expenses. The labor necessary to fence the field into successive areas, and the cost of providing feed troughs and watering facilities are expenses that should be considered. This trial conducted under practical farm conditions indicates that hegari stalks may be converted into beef economically, suggests a method for so doing, and emphasizes the need of carefully secured experimental data on the problem.

State Fair exhibit. The Animal Husbandry Department prepared and exhibited representative animals of the different breeds of University livestock at the 1931 Arizona State Fair. The University stock was awarded the following championships: Champion Rambouillet Ram,

Champion Rambouillet Ewe, Champion Hampshire Ram, Champion Hampshire Ewe, Champion Angora Buck, Champion Angora Doe, Champion Poland China Boar, Champion Poland China Sow, Champion Duroc Jersey Boar, Junior Champion Duroc Jersey Sow.

In addition to these championships many first, second, and thirds were taken, with no individual animal in the exhibit placing below third in the class.

The Cattleman's Convention. The 1932 convention of the Arizona Cattle Growers' Association was held in Tucson. The cattlemen were the guests of the University at lunch Tuesday, February 16, and held their afternoon sessions at the University. The College of Agriculture played a prominent part in the activities of the meetings. Dean P. S. Burgess, Director P. H. Ross, Regent F. J. Crider, C. U. Pickrell, Drs. G. W. Barr, and E. L. Scott are members of the staff who addressed the assemblage. The University Hereford herd was displayed for the visiting cattlemen.

BOTANY

J. J. THORNER

The time of the botanist is divided between teaching taxonomic botany in the College of Letters, Arts, and Sciences, and research and agricultural extension work in the College of Agriculture. During the past 2 years Miss Frances Hamilton has held a fellowship in taxonomic botany for which she has given from one-fourth to one-half of her time to the study and identification of plants that heretofore have not been studied technically. Miss Hamilton's work has been with economic plants, including weeds, poison plants, cacti, trees, shrubs, and flowers. With this arrangement it has been possible to complete a relatively large amount of plant study at small expense.

The study of the poison plants of the State has been continued. Fifty-eight species of poison plants have been studied and their identifications checked during the year and drawings in black and white have been made of these. About 25 species remain to be studied. It is planned to prepare this work at the earliest opportunity for publication as a bulletin.

A study of the browse plants has been undertaken and 54 were identified. This represents about one-half of the browse plants in Arizona. Drawings in black and white have been made of the ones studied. It will require considerable time to complete this work which is of importance to stockmen.

Considerable work has been done on the identification of the weeds of Arizona. Forty species have been completed and drawings also were made of these. The weed flora of the State is a large one and this group of plants is of great importance both to farmers and stockmen. Particular attention is being given to the distribution of weeds over the State and of conditions favoring their growth and spread.

Some additional work has been done on the ornamental plants of Arizona, about 50 additional kinds have been collected and studied. Due to the heavy teaching load it has not been possible to continue the studies in ornamental plants by localities, which was begun some years ago.

Considerable time has been given to work on the cacti, both native and introduced species. Nearly 100 kinds have been studied, including plants from Mexico and the neighboring states. The correspondence on cacti has continued heavy, often as high as one-third of all letters refer to some phase of cactus study.

Only a small amount of work has been done on the grasses and grass-like plants during the year, about 40 species having been collected and identified.

Miscellaneous. During the year the writer identified, prepared data for labels, and assisted in labeling 342 species of plants growing on the University Campus. As a result of this work a large number of the campus plants have permanent labels bearing the common and scientific names, the family name, and the habitat of the plant. The campus plants represent 73 families and include many of the finer ornamental trees, shrubs, and vines growing in the Southwest.

With the assistance of advanced students in botany the herbarium consisting of nearly 1,000 sheets of mounted specimens, has been reclassified and rearranged. The work required more than a year's time for completion.

During the year 1,500 letters and inquiries have been received and answered, relating to native and introduced plants, and more than 2,400 specimens of plants have been received from various sources and identified.

In addition to the foregoing the writer gave a month's time to agricultural extension work as follows: Making a display of native plants for ornamental planting at the State Fair; judging flower shows at Willcox and Yuma; preparing permanent mounts of economic plants collected in Santa Cruz County with the assistance of the county agent and of plants collected in other counties during the past 2 years, as follows: Yuma County, 28 mounts; Yavapai County, 55 mounts; Cochise County, 59 mounts; Santa Cruz County, 70 mounts. In this work particular attention has been given to weeds, forage plants, and poison plants.

DAIRY HUSBANDRY

W. S. CUNNINGHAM

The following is a brief resumé of work done on projects in the Department of Dairy Husbandry during the past fiscal year.

Effect of stages of maturity of Hairy Peruvian and Common Alfalfa Hay on milk production (No. 114 S). Each year part of a field of alfalfa is cut in the bud stage and the remainder in one-third-bloom or full-bloom stage. The hay thus secured is fed to lots of cows by the double-reversal method and records of production are kept. Up to the present time only the one-third-bloom and bud-stage hays have been compared in feeding value. In every case the bud-stage hay was relished more by the cows and there was less of it refused than of the one-third-bloom hay. The amount of milk produced has usually been greater when the cows were being fed bud-stage hay. This project is being continued.

The preservation of skimmed milk curd for poultry feeding (No. 70 S). Curd has been preserved in good condition for 6 months by the addition of formalin (40 percent formaldehyde), at the rate of 1:1000. "Shotgun cans" were used as containers. The preserved curd was relished by poultry and it was fed to young chicks with no more than normal mortality. Curd with formalin 1:1000 was preserved in good condition in hermetically sealed fruit jars for 2 years and 4 months. This work has been completed and manuscript has been prepared for publication.

Study of infectious abortion in dairy cattle (No. 177 S). Sixty-three dairy herds representing a total of approximately 1,700 animals have been tested for abortion. Approximately 85 percent of the 63 herds contained positive animals and about 25 percent of all animals tested were positive. Eight herds are being used as cooperators in this project and it is planned to increase this number to about 12. All cooperating herds are being tested every 30 days. The first herd to cooperate in this project was tested the first time on October 17, 1930. The positive and negative animals were separated with a double fence and milked in different sheds. All negative animals have remained negative and no infection has occurred among the heifers. Another herd containing over 100 animals which was tested the first time March 26, 1931, has had only five new reactors and four of these reacted to the second test which would indicate that infection occurred before separation. In this herd

the negative and positive cows were milked in the same stanchions. The negative animals were followed by the positive animals and the manger and floor were thoroughly washed after milking the positive cows. In fact there have been very few new reactors in any of the cooperating herds with one exception and in this case the animals were not kept carefully segregated.

The purpose of this project is to determine the extent of infectious abortion among the dairy cattle of the State, its relation to sterility, its effect on production, and to find a practical method for the eradication of this disease from the herds of the State.

Physiological varieties of bacteria in milk at the time of reduction in the Methylene Blue Reduction Test (No. 180 P). More than 100 samples of milk have been studied in this project. No effort will be made to analyze these data until a larger number of milk samples have been tested.

Study of properties of sweet buttermilk powder (No. 146 P). Analysis of both sweet and sour buttermilk powders which had been held in a desiccator for 16 months indicates that milk powders may be held indefinitely exposed to air without appreciable effect on the dispersibility of the powder provided the moisture content is low. Powder exposed to an atmosphere of relatively high humidity rapidly decreases in dispersibility.

The development of acid in milk lowers the dispersibility of the resultant powder. Sour buttermilk powder will absorb and retain more moisture than sweet buttermilk powder when exposed to the same relative humidities. When the maximum moisture content is reached, dehydration begins and lasts for a considerable period before equilibrium is established. The variation of the preheating temperature of five different lots of buttermilk from 142° F. to 172° F. did not seem to have any appreciable effect upon the moisture-absorbing qualities of the resultant powders.

Feeding sprouted oats to barren heifers. Sprouted oats were fed to seven purebred Jersey heifers which had failed to conceive after several services. Animals Nos. 28, 33, 35, and 36 were fed sprouted oats for a period of 150 days, while Nos. 26, 27, and 34 received sprouted oats for a 70-day period. No. 33 was the only one of the seven animals to conceive during the experimental period and this conception resulted from a service which occurred 84 days after the experiment began. No. 35 died 172 days after the oat feeding had been discontinued and post-mortem examination revealed that this animal was in calf, presumably

from a service which took place 56 days after the experiment had been discontinued. This heifer was given three doses of female sex hormones. The first dose was given on the seventeenth day after the oat feeding had been discontinued and conception occurred 39 days after the injection of the first dose of hormones. The ration while on experiment consisted of 5 pounds each of alfalfa hay, hegari stover, and corn silage, and 4 pounds of sprouted oats.

Three different sires were used on all the heifers except Nos. 33 and 36 which were bred to two different bulls. Other cows conceived readily when bred to either of the sires. All the heifers were examined by a veterinarian four times during the 150-day experiment. When examination showed the reproductive organs to be abnormal, the uterus was massaged and any cysts on the ovaries were ruptured. Nos. 26, 27, and 33 had normal ovaries while all other animals had cysts on the ovaries at some time during the experiment. The results of this experiment would seem to indicate that sprouted oats are not a cure for difficult breeding.

Pasture for young calves (No. 119 H and S). Alternate female calves dropped in the University herd were put on pasture when 2 days old. The other calves were kept in a dry lot. The pasture was the only difference in the feed of the two groups. The calves in both groups were given a full allowance of whole milk until 30 days old when the milk allowance was gradually reduced so that each calf was receiving one quart when 50 days old. When the calves were 60 days old, milk feeding was discontinued. As the milk allowance was reduced, calf-meal-gruel (1 pound concentrate mixture to 7 pounds of water) was substituted for the milk, pound for pound. All of the calves were given alfalfa hay and a dry grain mixture as soon as they would eat them. After 5 months of age, all of the calves were fed the same feed, including pasture, and given the same care. The six Jersey calves in the pasture group made an average daily gain to 5 months of age of 1.199 pounds. The average gain for the six calves in dry lot was 1.047 pounds.

The seven Holstein calves on pasture made an average daily gain of 1.684 pounds to 5 months of age as compared to a gain of 1.729 pounds for seven calves in dry lot. One calf in the pasture group made a gain of only 1.287 pounds which was considerably less than that of any other Holstein calf. The average gain of the other six calves in the pasture group was slightly more than that for the dry-lot group.

The average weight of the Jerseys on pasture at 1 and 2 years old was 484.6 and 746 pounds respectively as compared to an average of 444.6 and 671 pounds for the dry-lot group. The average weight for

the Holsteins on pasture at 1 and 2 years old was 704 and 1,112 pounds respectively while the dry-lot group averaged 640.9 and 1,073 pounds. The average height at the withers of the Jerseys on pasture was 35.166 inches at 5 months old. The average for the dry-lot calves was 33.705 inches. The Holsteins on pasture averaged 40.60 inches in height at 5 months and the average for the dry-lot calves was 39.617.

A large percentage of the Jersey heifers dropped in the University herd for several years had been difficult to breed. Four of the six Jerseys on pasture conceived with the first service, one was bred four, and one six times. In the dry-lot group only one heifer conceived by the first service while one was bred twice, one four, two five, and one six times before conception.

ENTOMOLOGY AND ECONOMIC ZOOLOGY

C. T. VORHIES

During the past year this Department, formerly Entomology, has been expanded in personnel, in name, and in the scope of its work.

Dr. E. D. Ball, an entomologist of international reputation, was appointed a full-time member of the department's teaching and research staff; and Assistant Professor A. A. Nichol, formerly of this Department, but more recently engaged with other duties in the University, is now a part-time member of our staff. Dr. W. P. Taylor, Senior Biologist, United States Biological Survey, is now officially affiliated with this Department. Throughout the 15 years of its existence, this has been officially designated as the Department of Entomology, although frequently called upon for advice and assistance in the broader field of economic zoology. The increasing importance of the latter phase of the work has now been recognized in the departmental title and organization.

Dr. E. D. Ball in the fall of 1931 took up an important study of the grasshoppers of the State, giving special attention to the range-grasshopper problem. Findings already of some interest in this work are: that the five most injurious species (on open range) are all short-winged (non-migratory) and that none of them have previously been listed as injurious; that a number of species are beneficial, feeding on injurious weeds; that serious injury is usually local in character; that one of the worst outbreaks of the year was checked and cleaned up by a migratory flight of hawks; that disease killed 60 percent of the hoppers in the Sulphur Spring Valley in the early fall, thus reducing egg-laying; and that the common grasshoppers, injurious to cultivated crops in southern Arizona, have entirely different egg-laying habits from those of the states north of Arizona, which creates a different and much more difficult control problem. Dr. Ball is also investigating the *Hemiptera*, or true bugs, injurious to alfalfa in the seed-growing districts near Yuma.

Dr. L. P. Wehrle has devoted much time to a study of the scale insects of Arizona, an investigation begun some time ago. Not only has much laboratory work been done, but life-history notes have been taken as opportunity offered. Much work has also been done on aphids of Arizona, both in making permanent mounts and in life-history observations. This economically important group of plant pests is related to the scale insects and requires the same exacting methods of work. Dr. Wehrle has also added materially to our collections and records of other economic insects, and has given attention to parasitic insects and to certain species of medical importance.

Work on the green June beetle, nearly completed some time ago, is being prepared for publication by Mr. A. A. Nichol, and should be ready in the near future. A publication, "Control of the Harvester Ant," Bulletin No. 138, by the same worker appeared during the past year.

The head of the department has given a part of his time for a period of years to studies of rodents and rabbits in relation to agriculture, especially the grazing ranges, in cooperation with Dr. W. P. Taylor. Much time this year has been devoted to the preparation of an extensive bulletin on the jackrabbits, which is now ready for the press. Work is also well started on the wood rat, or pack rat, the next animal to be intensively studied on the grazing ranges.

A project on the water relations of desert animals has received regular attention and promises interesting results.

Considerable study has been given to the citrus-thrips problem, and an attempt is being made to secure certain climatic data which may have an important relation to damage by this pest.

In response to numerous inquiries an article on termites was prepared for distribution in mimeographed form.

Some preliminary work has been done, and definite projects are being planned for investigations by Mr. A. A. Nichol and the head of the department on certain of the principal game animals of the State, such as deer, antelope, elk, and wild turkey. These constitute an important asset in themselves, and their relation to grazing ranges and thus to the grazing industry is not only important but little understood, and hence deserving of study.

Mr. D. M. Gorsuch is working under direction of this Department on an intensive and extensive study of the Gambel quail. A special fellowship fund for this investigation has thus far come from outside the State. Interesting and important results are being secured.

HORTICULTURE

A. F. KINNISON

The following is a brief resumé of work done on projects in the Department of Horticulture during the past fiscal year.

Citrus studies (No. 129 P and No. 166 P). Irrigation studies with Marsh grapefruit on the Yuma Mesa, carried on in collaboration with the Department of Agricultural Engineering, has progressed through the tree development stage and a progress report has been made (Technical Bulletin No. 37).

Comparative tree development under the differential irrigation treatments has been determined by measuring the trunk of the plot trees annually. The reliability of such measurements as an index of tree growth was determined by the complete removal and weighing of 100 plot trees during the course of the study. A coefficient or correlation of 0.98 was found to exist between the area of cross-section of the tree trunk 4 inches above the bud union and the total air-dry weight of the plant.

At the close of the fourth growing season, the trees irrigated weekly during the growing season were 3.1 times larger than those irrigated at 6-week intervals; 2.6 times larger than those irrigated every 4 weeks and 1.5 times larger than those irrigated at 2-week intervals. The lower soil temperatures resulting from frequent irrigations were favorable for root growth, and account in considerable measure for the greater growth of trees on plots receiving such treatment. Root distribution was influenced by the frequency of irrigation. The trees most frequently irrigated developed more and larger roots near the soil surface than did those less frequently irrigated. This condition was more marked with 2-year-old orchard trees than with the 4-year-old trees studied.

Trees on the less frequently irrigated plots were not only smaller but were apparently weak physiologically as evidenced by greater susceptibility to damage from desiccating winds and from frost.

In cooperation with the Bureau of Agricultural Engineering of the United States Department of Agriculture, intensive soil-moisture studies were made throughout the year in mature Navel-orange and grapefruit groves in the Salt River Valley. Data are compiled giving the month-to-month use of soil moisture by the trees in each location. Similar data for comparison were secured from two locations among mature date palms in the University Date Garden. The average monthly use of water, in acre-inches, by these orchard plants for the months of June,

July, and August are: Navel orange, 3.07; grapefruit, 5.74; date, 5.51. With grapefruit and dates the rate of use of soil moisture increased to a maximum in June and early July with decreasing usage during the balance of the summer. With the Navel orange, usage during June, early July, and September was somewhat greater than during the midsummer season. A comparison of water usage between a normal Navel-orange tree and one of equal size but with chlorotic foliage shows that, for a period of 1 year, the normal tree used water at the rate of 27.83 acre-inches per acre while the usage of the chlorotic tree was at the rate of 24.68 acre-inches per acre. The normal tree withdrew moisture from a slightly greater depth than did the chlorotic tree.

Fertilizer materials carrying nitrogen, phosphoric acid, and potash have been applied to carefully selected plot areas in mature Navel-orange and grapefruit groves on the Yuma Mesa and in the Salt River Valley. The materials applied supplement a basic, bulky, organic-matter application. Quantitative determinations of sugar and acid content of the fruit from the several plots and checks at two stages of maturity reveal no significant difference in the amounts of these present. Yields were not measurably influenced by the treatments. Iron-sulphate solution injected into the trunk of a chlorotic orange tree produced slight change in tree condition. Phosphoric acid has been applied to the soil in different manners; in one case with trenched manure, in a second in post holes, and in a third in solution in furrows followed immediately by a 3-inch irrigation. Analysis of the soil for soluble phosphate indicates that the best distribution of the material is obtained when dissolved in the irrigation water.

On the Yuma Mesa Citrus Station where the navel orange bears very light crops, an increase in yield of approximately 75 percent resulted from girdling the trees when in full blossom.

There appears to be no difference between the Davis Seedless variety of grapefruit and the Marsh in fruit and tree characters or in the time of maturity of the crop.

The Norris, or Hamlin, seedless variety of orange is producing on the Yuma Mesa, but the fruit is rough and so lacking in juice and quality as to be worthless commercially. The variety is being planted for trial in the Salt River Valley.

The Mexican lime continues to bear heavy crops at the Yuma Mesa Station. Four trees 8 years of age averaged 350 dozen fruits each in 1931 as compared with 150 dozen for the Thornless and 60 dozen for the Bearss seedless.

Date Studies (No. 26 S. and No. 182 P.). The 1931 date season was characterized by heavy losses of fruit of practically all varieties grown at the University Date Garden due to heavy rains and prolonged humid weather. The losses ranged from 100 percent with the Rhars and Deglet Noor varieties to 15 percent with the Maktum, Khadrawi, and Sayer and 10 percent with the Kustawi. The following table presents the losses for the principal varieties. The 1930 losses are given for comparison, as is also the specific type of loss for each variety.

Variety	Ripening period	Pct. loss		Remarks
	1931	1930	1931	
Rhars	Aug. 10-Oct. 1	30	100	Splitting, souring, fungus
Deglet Noor	Oct. 15-Dec. 1	60	100	Fungus spot, black nose
Saidy	Oct. 1-Dec. 1	50	60	Fungus spot
Hayany	Aug. 15-Nov. 1	30	50	Checking, black nose, souring
Iteema	Oct. 1-Nov. 15	25	60	Checking, souring
Halawi	Sept. 1-Nov. 1	10	40	Checking, souring
Kustawi	Sept. 15-Nov. 1	10	10	Blistered fruit
Khadrawi	Aug. 15-Oct. 15	0	20	Shrivel
Berhi	Sept. 1-Oct. 15	5	60	Souring
Zehedi	Oct. 1-Nov. 15	25	85	Fungus, souring
Maktum	Oct. 1-Dec. 15	0	15	Splitting
Sayer	Sept. 15-Nov. 15	0	15	Fungus

A comparison of four methods of fruit thinning showed that no one had particular merit over the others in so far as the effect upon fruit size was concerned. All methods resulted in larger fruit than from unthinned palms.

Fruit-growth studies in 1931 indicate that with pollination periods ranging from March 17 to April 1 and the time of ripening from August 15 to December 15, fruits of three varieties of dates (Hayany, Maktum, and Deglet Noor) attain maximum size at approximately the same time.

As a result of treating a mature Rhars palm which failed to respond following defoliation and torching for the control of *Parlatoria* scale, offshoots developed immediately below the growing point of a 30-foot palm. Roots from both the young offshoots and from the injured portion of the mother-palm trunk developed in a box of soil supported on scaffolding. Later the top of the palm was cut off immediately below the whorl of offshoots, lowered to the ground, and planted.

More offshoots have since developed and these as well as the mother palm (top) appear to be developing in a normal manner. This is the first successful attempt known to us of propagating a mature palm vegetatively except by means of offshoots.

Maturation of unprocessed date fruit at five stages of maturity, ranging from green to fully tree-ripe, by placing in cold storage indicates that a very attractive and satisfactory product can be obtained by such a method. The objectionable darkened color of the fruit resulting from heat maturation was lacking in the storage samples. Determinations of moisture and sugar content were made on all lots as they came from the palm and at monthly periods on the stored fruit.

The use of a number of vegetable oil sprays, alone and in combination, to coat the fruit in an attempt to reduce fruit loss due to rains and high humidity resulted in slight benefit to the fruit so treated as compared to the untreated controls. The greatest percentage of commercial fruit under any one treatment was 34.7 for a combination spray of sesame oil and sodium oleate in ethyl alcohol, as compared with 27.2 percent commercial fruit from the control.

Pecan Studies (No. 181 P). The continued satisfactory fruiting of pecan trees in many districts of southern Arizona has given rise to a rapid extension of pecan plantings during the past few years. With this growth of the pecan industry in Arizona, there has come a demand for more knowledge of pecan culture and for the solution of certain problems that have arisen. In answer to this demand, more extensive investigations have recently been initiated by the Experiment Station. Sufficient time has not yet elapsed for the publication of definite and final results, but the nature and progress of investigations are indicated by the following.

Studies have been undertaken to learn the pollination requirements of different varieties. This information will make it possible to intelligently select for planting such combinations of varieties as to cause effective pollination. Crosses were made during the 1932 blossoming season. All unpollinated pistillate flowers of the Burkett and Schley varieties dropped at 5 to 6 weeks after receptivity. Only a small percent of those of Kincaid dropped. Pistillate flowers of each variety tested "set" when pollinated with any of several pollens. The effect of different pollens on the "filling" of the nuts will be observed at harvest. Some nuts drop from the trees during the spring and early summer. The earliest of this "drop" appears to be due to the abscission of the cluster stem. Later, individual nuts are shed from many clusters. This latter

dropping coincided to some extent this season with the drop from unpolinated clusters. The extent to which it is related to pollination has not been determined. There is some evidence that the earlier cluster drop is related to quality and character of the shoot on which the cluster is borne.

The problem arising from the failure of some nuts to fill is being investigated through the pollination studies mentioned above and through studies of nutritional factors associated with filling. Field plots involving various fertilizing and pruning practices are being used as a possible means of shifting the nutritional plane within the tree. Such practices as girdling and defoliating are being used with a view of producing wide nutritional extremes under which the character of filling may be observed. Results of these studies cannot be determined until harvest.

Studies of pecan nursery practices were initiated during the past winter on the Experiment Station Farm in the Yuma Valley. Seeds from many different varieties and sources were obtained from various parts of the pecan belt. Wide differences in germination of different seeds and subsequent growth of seedlings are apparent.

In 2-year-old pecan plantings on the Yuma Valley Experiment Farm, plots have been established to compare the effect of various cultural treatments on the growth of young trees. With these same trees, studies of tree training are in progress. Several methods are being devised to train young orchard trees to a more permanent and productive type.

Studies of pecan rosette were begun during the winter of 1931-32 when soils from many healthy and affected groves were analyzed for soluble-salt (alkali) content. These analyses have been extended during the summer just past. Determinations of the pH value of soils from healthy and affected groves have also been made. These studies have revealed no clear relation between soluble-salt content of the soil and rosetting of the trees. Similarly the occurrence of rosette has not been found to be consistently related to the pH of the soils.

During the early summer of 1932 chemical studies were initiated. Trees were treated by placing the chemical in holes bored in the trunk of the tree, by injecting solutions into the tree, by spraying the tree, and by dipping affected leaves. Chemicals used in this work have been: commercial iron sulfate and treble super-phosphate, chemically pure potassium phosphate, ferric phosphate, ferric citrate, ferric ammonium citrate, ferric chloride, zinc chloride, manganous acetate, magnesium acetate, magnesium citrate, acetic acid, tannic acid, sulfuric acid, and U.S.P. zinc sulfate.

Severely affected trees have shown marked improvement from treatment with the two zinc compounds. After placing 2 to 12 grams of zinc

chloride, or sulfate, in holes in the trunks of 2- to 8-year-old severely rosetted trees, uniformly healthy growth has resulted consistently. Check, untreated trees failed to recover, generally becoming more severely affected. The treated trees continued healthy. A similar response has been obtained by injecting 1 pint of a 1-percent solution of zinc chloride into the tree. Spraying affected trees with a 0.1- and with a 0.01-percent solution of zinc chloride caused young leaves present at the time of spraying to become green and remain so but growth made after the treatment was not always healthy. Dipping of young affected leaves or leaflets in 0.05-percent solution of zinc chloride or a 0.1-percent solution of zinc sulfate was uniformly followed by a greening of the leaf and its healthy development.

Commercial iron sulfate which may contain an appreciable amount of zinc, has given somewhat similar results although not so striking or consistent, and less permanent in the case of the material placed directly in the tree. All other materials used have produced no apparent beneficial effect.

HUMAN NUTRITION

MARGARET CAMMACK SMITH

The Department of Human Nutrition maintains an animal-feeding laboratory for the study of nutrition problems, and a chemical laboratory for the analytical work involved. Albino rats, guinea pigs, and dogs are used for experimental animals.

Vitamins in dates (No. 153 P). Measurement of the vitamin A, B, C, D, and G content of three varieties of Arizona-grown dates has been completed during the past year and published as Arizona Experiment Station Technical Bulletin No. 34 entitled "The Vitamin Content of Three Varieties of Arizona Dates." The Thoory as a representative of the dry date, the Deglet Noor a semi-dry date, and the Maktum a soft, fresh date were selected for this study. The accepted quantitative methods of vitamin measurement have been followed and the results have been expressed in terms of Sherman's vitamin units. The dates were found to compare favorably with other fruits as a source of vitamins A and B and to lack measurable amounts of vitamins C and D.

Effect of curing process on vitamin A and D content of alfalfa (No. 152 P). In cooperation with Mr. Ian A. Briggs of the Agronomy Department, a study has been made of the effect of curing periods of different lengths upon the vitamin A and D content of alfalfa. The alfalfa was spread out by hand and allowed to lie upon the field for periods of $2\frac{3}{4}$, $4\frac{3}{4}$, $6\frac{3}{4}$, $20\frac{3}{4}$, and $24\frac{3}{4}$ hours after which treatment it was brought in and the curing completed in the darkened curing house. The vitamin A and D contents of each of these samples were compared with the vitamin content of a sample taken from the field immediately upon cutting and cured in the dark. The results show a marked destruction of vitamin A which becomes greater as the time of exposure is increased. A loss of 25 to 33 percent of the vitamin A content, compared with the cured-in-the-dark samples, resulted from allowing the alfalfa to lie on the field for the $2\frac{3}{4}$ -hour period from 11:15 a.m. to 2 p.m., a 75-percent destruction resulted when the alfalfa was allowed to lie on the field until 8 a.m., the next morning. This loss was increased to 84 percent upon a further 4-hour period of exposure until 12 noon the second day.

On the other hand, some synthesis of vitamin D was found to occur as a result of exposure on the field. Prolonged feeding of the cured-in-the-dark sample which resulted in no healing of the rachitic lesions in the experimental rats indicated the absence of appreciable amounts of

vitamin D. Alfalfa which had been exposed for the 24 $\frac{3}{4}$ -hour period, however, possessed mild calcifying properties which the cured-in-the-dark sample did not have.

A great synthesis of vitamin D occurred when alfalfa was allowed to lie in the swath for a period of 1 week. There was, however, an accompanying destruction of 96 percent of the vitamin A. The high feeding value of alfalfa can, therefore, be best preserved by cutting the period of field exposure to a minimum. Two papers based upon this material have been accepted for publication in the Journal of Agricultural Research. The titles of these papers are "The Relation of the Curing Process to the Vitamin-A Content of Alfalfa," and "The Antirachitic Value of Alfalfa as Affected by Different Periods of Exposure to Arizona Sunshine in the Curing Process."

Mottled enamel of human teeth (No. 168 P). In June, 1931, this Department published in Technical Bulletin No. 32, entitled "The Cause of Mottled Enamel, a Defect of Human Teeth," proof that mottled enamel of human teeth is caused by the toxic effect of fluorides present in the drinking water supply of the afflicted persons. A briefer report entitled "The Cause of Mottled Enamel," has been published in the Journal of Dental Research, Vol. 12 (1932), pp. 149-157, and also in Dental Survey, March, 1932. Mottled enamel was experimentally produced in rats by feeding the residue obtained by evaporation of the water from St. David, Arizona, a community in which all native inhabitants have mottled enamel, and also by the feeding of sodium fluoride. Analyses of waters from St. David revealed the presence of abnormally high concentrations of fluorides. Subsequently, mottled enamel has also been produced in dogs and guinea pigs by the feeding of fluorides, and in rats by the subcutaneous injections of fluorides.

In the past year an investigation has been in progress with the two-fold purpose of disclosing other endemic areas in Arizona and obtaining information which would throw light on those concentrations of fluorides which interfere with tooth development. Examination has been made of the teeth of the school children in at least 150 communities in Arizona, and the drinking water supply of the various communities sampled and analyzed for fluorides. This material has recently been published as Technical Bulletin No. 43, "Mottled Enamel in Arizona and its Correlation of Fluorides in Water Supplies."

Investigations into the mode of action of fluorides are under way. Dr. Isaac Shour of the University of Illinois Dental College is making

histological examinations of the teeth of our fluoride-fed animals. The effect of fluoride feeding upon the chemical composition of rats' teeth has been studied and a preliminary report read before the International Association of Dental Research and published in the *Journal of Dental Research*, Vol. 12, No. 2, for June, 1932, entitled "Studies in the Metabolism of Fluorides I: The Effect of Fluorides upon the Chemical Composition of the Incisors of Albino Rats." These experiments have been carried out to determine the effect of sodium-fluoride feeding upon the chemical composition of the teeth of albino rats in the concentration (0.05 percent) which has resulted in the production of mottled enamel. One upper and one lower incisor from each of 4 rats were grouped, extracted in alcohol and ether, dried to constant weight and ashed. The ash was dissolved in dilute hydrochloric acid and aliquot portions analyzed for calcium and phosphorus. The average results of analyses of the sodium-fluoride-fed rats and the controls on the same basal diet but without the addition of sodium fluoride show no significant differences in percentage of ash, percentage of calcium and phosphorus, or in the ratio of calcium to phosphorus. Thus, changes in the calcium and phosphorus content of the fluoride-fed animals which have been suspected from the observed outward abnormalities, and suggested by histological studies of other workers, are of apparently too small order to be detected by chemical analyses as usually made.

Dental abnormalities produced by vitamin-A-deficient diets have been observed and described in this laboratory, and chemical analyses of the incisors for the purpose of obtaining information on the nature of the observed changes have been made. This work also has been reported in the *Journal of Dental Research* entitled "Changes in Incisors of Rats Fed a Vitamin-A-Deficient Diet."

The effect of fluorides upon the metabolism of calcium and phosphorus is being studied by means of balance experiments on rats, dogs, and human beings. Dogs are also being used in a study of blood composition as influenced by feeding.

The relation of a possible dietary deficiency of calcium and phosphorus, or a faulty calcium:phosphorus ratio, as a contributing cause to the occurrence of mottled enamel among St. David children has been investigated by Miss Ruth Leverton and the results of this study have been published in the *Journal of Home Economics* entitled, "The Relation of Calcium and Phosphorus in the Diet to the Cause of Mottled Enamel of Human Teeth." This is a quantitative dietary study with special reference to calcium and phosphorus and has been made on 19 children in St. David, Arizona, a community where mottled enamel is endemic.

Sixteen of the children had mottled enamel and three did not. Individual composites were made of the food intakes during the period of study and the composites were analyzed in the laboratory for calcium, phosphorus, nitrogen, and calories. The food intake of the children who had mottling was compared with that of those who did not have mottling and all intakes were compared with dietary standards for optimum growth and nutrition, considering every possible deficiency in its relation to the presence or absence of mottled enamel in the children.

The daily calcium intakes of the children with mottled enamel averaged 1.15 grams and 1.18 grams for those without mottled enamel, both of which compare favorably with Sherman's standard of a gram per day per child. The availability of this calcium was questioned because only two children drank more than a pint of milk a day.

The daily phosphorus intakes of the children with mottled enamel averaged 1.06 grams and 1.04 grams. These are less optimum than the actual intakes of calcium when compared to Sherman's standard of 1.16 to 1.48 grams per child per day. The ratio of calcium to phosphorus however in the diets was practically normal for both groups.

The protein and energy intakes were adequate in all cases. The consumption of fresh fruits and vegetables was calculated as an indication of the intake of vitamin C. The children with the severest mottling and pitting had a much lower intake than the other children of either the mottled or the non-mottled group and the possible significance of this in affecting the severity of the mottling was suggested.

The results which have been reported indicate that an adequate calcium and phosphorus intake in childhood during the years of enamel formation will not prevent the development of mottled enamel if the child is exposed to the environmental factors of an endemic community.

The supplemental feeding of the 30 first-grade school children of St. David started in the fall of 1930 for the purpose of possible prevention of mottling of the permanent teeth of these children, is still being carried on. The codliver oil and vitamin D concentrates used in this work have been contributed by E. R. Squibbs and Company. Periodic examinations are made and record is being kept of the effect of the supplemental feeding upon the teeth and general physical condition of the children.

Biological efficiency of hegari proteins (No. 167 P). Following up the work proving the inadequacy of the proteins of sorghum grain as the sole source of protein in the diet, experiments are in progress to determine the biological efficiency of the proteins in hegari, their amino-

acid deficiencies and the supplemental value of common commercial protein concentrates. By carefully conducted paired-feeding experiments, the amino-acids tryptophane and cystine have been shown not to be the first limiting factor of the proteins of hehari. The marked supplemental effect of gelatin suggests lysine as the limiting amino-acid, and paired-feeding experiments with lysine are under way. The supplemental value of commercial protein concentrates such as cottonseed meal, tankage, meat scraps, skimmilk powder, alfalfa, etc., is being investigated by the same methods. Conclusions are being based upon gain per gram of protein eaten, and upon nitrogen-balance experiments.

PLANT BREEDING

W. E. BRYAN AND E. H. PRESSLEY

The work of the Plant Breeding Department has been carried on under four projects, *viz.*: (1) Breeding for improved hay and seeding qualities in alfalfa; (2) Increasing the yield, strength of straw, and smut resistance in wheat; (3) Breeding for improved fiber qualities and plant characters in cotton, and (4) A study of the inheritance of certain characters in seedling dates.

Inheritance of economic characters in pure lines of alfalfa (No. 4 A). In improving the quality of alfalfa it is desirable to know to what extent the various factors of quality can be fixed in the strain or variety. The quality factors upon which the selection of plants and progenies has been based in this project are as follows: 1. Leafiness, 2. Size of stems, 3. Ability to set seed, 4. Leafiness and seed setting combined, 4. Hairiness, 5. Uprightness. In the summer of 1931 data regarding these quality factors were taken on 631 first-self-pollinated-generation progenies at the Yuma Valley sub-station. These progenies originated from individual self-pollinated plants selected from a field which had been planted with seed from one of the local, common-alfalfa fields. Data on these progenies seem to justify the following tentative conclusions:

Since 95 percent of these 631 progenies were very uniform within themselves for all the important characters, it appears that cross pollination in alfalfa in Arizona is not as prevalent as has been supposed.

Lack of uniformity in commercial alfalfa fields of Arizona is due mainly to mechanical seed mixtures between diverse types. The very great diversity between these progenies, some of which possess high quality, indicates that the better commercial fields in Arizona are excellent foundation stock from which to breed up improved strains.

In general the leafy progenies produced less seed than the less leafy, although a sufficient number of exceptions to this rule were found to justify the conclusion that leafiness and seed-setting ability are not necessarily antagonistic.

In order to determine the inheritance of these quality factors, self-fertilized seed was taken from 316 plants of 18 different progenies. These progenies were planted in the fall of 1931. Data will be taken from these progenies during the summer of 1932.

Wheat breeding. Bunt (Tilletia) resistance studies (No. 6 A). Susceptibility to bunt of four leading Arizona wheat varieties as determined by inoculation with bunt spores is as follows:

<i>Variety</i>	<i>No. plants tested</i>	<i>No. plants with bunt</i>	<i>Pct. with bunt</i>
Sonora	175	144	82.2
Early Baart	207	155	74.8
Pusa	193	93	48.1
Escondido	174	100	56.5

; In comparison with the above varieties, Hussar, Ridit, and Hope wheats have proved to be immune to bunt. The following crosses have therefore been made in an attempt to combine resistance to bunt with the desirable economic characters of the best Arizona wheats:

Hope × Sonora
 Ridit × Pusa
 Ridit × Escondido
 Hussar × Sonora
 Early Baart ⇌ Ridit

The bunt reaction in populations grown from inoculated F₂ seed of the above crosses is as follows:

<i>Cross</i>	<i>No. plants tested</i>	<i>No. plants with bunt</i>	<i>Pct. with bunt</i>
Hope × Sonora	315	116	36.8
Ridit × Pusa	328	25	7.6
Ridit × Escondido	315	34	10.7
Hussar × Sonora	311	25	8.0
Ridit × Early Baart	310	36	11.6

From the above data it appears that resistance to bunt is a dominant character, which makes the problem of fixing true-breeding, resistant types more difficult than where resistance is recessive. One hundred fifty-eight inoculated progenies from F₃ seed of each of the following crosses were planted January 20, 1932:

Hope × Sonora
 Ridit × Pusa
 Ridit × Escondido
 Hussar × Sonora

Forty seeds of each progeny were planted and the seeds were spaced 1 foot apart in the row with 30 inches between the rows. Resistant

progenies from among these which also have other desirable characters will be selected for further testing. It is believed that true-breeding, resistant strains with high yield and quality can be produced in 2 more years.

GRAIN TEXTURE

Segregation of *hard* and *soft* textures in a cross between hard Baart and soft-grained Sonora. The F_1 plants produced *hard* and *soft* grains as follows:

<i>Plant No.</i>	<i>No. soft seeds</i>	<i>No. hard seeds</i>
1	131	130
2	127	134
3	143	128
4	79	108
5	94	101

Selected hard and soft seeds from the above were planted and the results obtained from each kind of seed are shown in the following table:

<i>Texture of F_2 seed</i>	<i>No. plants with hard grains only</i>	<i>No. plants with hard and soft grains</i>	<i>No. plants with soft grains only</i>
Hard	254	308	0
Soft	0	205	336

From the data in the two foregoing tables it is evident that: First, hard texture in this cross is a definitely heritable character; Second, dominance is absent, and multiple factors differentiate the two types of texture. From other data it has also been determined that hard texture is not linked or correlated with any of the major economic characters of wheat which makes it possible to combine hard texture with any desirable set of characters.

In order to test the rate of change of proportions of hard and soft seeds in a mixture from year to year of a pure, hard-grained wheat and a pure, soft-grained wheat, the following mixture was made up on the basis of grain count in the laboratory and grown in the field for 6 years:

75 percent hard grains and 25 percent soft grains.

The percentage of soft grains by years found in this mixture is as follows, ending with the crop of 1931:

27.9, 36.0, 46.2, 54.5, 64.8, 83.2

Comparative tillering studies with these two strains indicate that the soft displaces the hard because of the greater number of heads per plant in the soft strain. These results explain, at least in part, the apparent change from hard to soft texture of certain wheat varieties, and call attention to the importance of growing pure strains, not only with cereals but with all crops.

Cotton breeding (No. 47 A). In the spring of 1931, 225 plants of Upland were selected for planting the 1931 crop of cotton. With the seeds from these plants, 419 rows, each 75 feet long, were planted in May of 1931.

In the fall of 1931 each of these rows was studied in the field for uniformity and other vegetative characters. A study was also made in the field of the length and uniformity of the lint upon those plants whose vegetative characters were considered satisfactory. In this manner from 12,000 to 15,000 plants were inspected and preliminary combings were made on approximately 3,000 plants. Of these 3,000 plants, about 600 were considered worthy of more careful examination and were harvested and brought into the laboratory. A more careful elimination of plants in the field was impossible because of an excessive amount of rainfall which limited to a great extent the amount of time that could be devoted to this purpose. At the time of harvesting, a sample consisting of one lock from each of 20 different bolls was taken from each plant. This was done for the purpose of getting a representative sample from each plant and for convenience of handling in the laboratory. One seed was taken from each of these locks, care being exercised to take seed from different parts of the locks. This sample of 20 seeds coming from different parts of the locks from 20 different bolls was used to determine the length of lint and the amount of variation in the length of lint. Three hundred seventy of the 600 plants harvested were discarded in this manner because of a lack of uniformity in lint length.

The 20 seed samples from the remaining 230 plants were combed and measured. A device was made for quickly and accurately measuring the uniformity of the length of lint in terms of degrees of "butterfly" or the shortening of the lint on the small end of the seed. The average amount of "butterfly" was determined for each plant. The samples were then filed away for future reference.

It was thought that a sample of cotton showing very little variation in length of lint in a combed sample might still contain a rather high

percentage of short fibers scattered among the long fibers. In order to test the accuracy of this assumption, a sorting machine was made upon which a combed sample could be placed, the various lengths of lint pulled from the seed, and the percentage of the total amount of lint in each length determined. Ten seeds from each of the 230 plants were combed and run over this sorting machine. In this manner the percentage of lint in eighths of an inch was found for each plant.

The following table shows the difference found in the 230 plants studied :

	<i>Highest</i> <i>Pct.</i>	<i>Lowest</i> <i>Pct.</i>	<i>Difference</i> <i>Pct.</i>
Percentage of lint in modal $\frac{1}{8}$ in.	40.0	24.2	15.8
Percentage of lint in modal $\frac{1}{4}$ in.	69.5	46.3	23.2
Percentage of lint in modal $\frac{3}{8}$ in.	79.0	61.2	17.8

The table below shows the correlation between the degree of "butterfly" as obtained from the 20 seed samples and the percentage of lint in the modal $\frac{1}{8}$, $\frac{1}{4}$, and $\frac{3}{8}$ inch as obtained from the 10 seed samples taken from the same 20 locks.

Correlation between the degree of "butterfly" and

Modal $\frac{1}{8}$ in.....	0.2119 ± 0.042292
Modal $\frac{1}{4}$ in.....	0.28062 ± 0.040795
Modal $\frac{3}{8}$ in.....	0.16879 ± 0.043021

A comparison of the following two plants is interesting. The first has an average degree of "butterfly" of 4.4 degrees which is next to the lowest of all plants studied, while the second has an average of 22.2 degrees of "butterfly" which is the highest of all plants studied.

	<i>Percentage of lint in modal</i>		
<i>Average degree of "butterfly"</i>	$\frac{1}{8}$ in.	$\frac{1}{4}$ in.	$\frac{3}{8}$ in.
4.4	24.2	46.3	61.2
22.2	27.8	55.2	68.0

Plant No. 1, while one of the most uniform in appearance in so far as can be determined from a combed sample had the lowest percentage of lint in the three classes studied. On the other hand plant No. 2 which was much less uniform in appearance had a much higher percentage of lint in each of the three classes studied, and of course a much smaller percentage of short waste.

It is readily seen from the above figures that an accurate determination of the amount of short fiber in a given sample of cotton can not be made from a simple inspection of a combed sample.

Selections for planting in 1932 have been made on the basis of the percentage of long lint after the length of lint and total percent of lint have been found satisfactory.

The difference among the plants in the amount of long and short fibers is great enough to offer a good field for selection, and it is felt that further work along this line may result in developing one or more strains of cotton having much less than the average amount of waste fiber.

A paper entitled, "A New Type of Cotton Sorter," has been accepted for publication in the Journal of the American Society of Agronomy. A detailed description of the materials used, method of construction, and use of the sorter is given. The paper also contains a discussion of the methods used in sampling, the preparation of the samples for sorting, and the results obtained by the use of the sorter in the study of plant selections made from the crop of 1931. Tables are given which show the differences in the percentages of lint of various lengths obtained by sorting samples from approximately 230 individual plants. Photographs showing the sorter and its use are included.

Date breeding (No. 15 S). During the past year data have been taken on the flowering and fruit characters of 713 second-generation date seedlings obtained originally from the Deglet Noor variety. Some of the most promising of these females were pollinated with pollen from certain of their brother males in order to obtain seed for planting the third seedling generation. The plan of this project is to establish several inbred lines with a view to studying the effect of inbreeding on the date palm, and at the same time to obtain data which will throw light on the inheritance of fruit and flowering characters. During the coming year the seeds obtained by controlled pollination will be planted for the purpose of obtaining the third seedling generation. This is a long-time project and will require another seedling generation before the data will permit drawing any conclusions.

PLANT PATHOLOGY

J. G. BROWN

The absence of one member of the staff on sabbatical leave during the first semester of the year necessitated the distribution of work in teaching and research between the two remaining members. In addition to the regular projects carried by the Department, calls for aid in combating plant diseases and the diagnoses of infected plants received by mail consumed much time. For these reasons, study on the projects was somewhat limited.

Bacterial rot of lettuce (No. 58 A). Bacterial rot, or slime, has caused heavy losses in the lettuce fields of Arizona for a decade. It has also been reported from other states. The disease is characterized by a purple-brown discoloration of the veins usually most evident at the tip and along the margin of the leaf, water-soaking of the intervenar parenchyma and the death of the leaf. In other cases, a small water-soaked spot appears on the leaf, enlarges, and by coalescence with similar spots, forms a necrotic area which varies in size. The outer leaves frequently become dry and parchment-like. However, the leaves protected from drying become a wet, slimy mass, so that when the infected head is grasped, the fingers break through the thin, dry outer layer and penetrate into the decayed central part. Here in the center the dry brown stage evident in the surface leaves is lacking, and the water-soaked spots disintegrate at once into greenish to brownish slime. Owing to the nature of the outer leaves of lettuce heads in both diseases, slime has been confused with at least one type of tipburn. Bacterial slime of lettuce is worst in the spring crop when the days are hot and the nights cold, although it may be present at other times in slight infections which are overlooked by the untrained observer. Under the former condition tipburn is also abundant. Studies made in this laboratory are believed to show that the initial stages of bacterial slime and tipburn may be the same.

When the daily range of temperature is great, examination of the leaves of lettuce with the microscope reveals ruptured tissues. Small fissures occur in the epidermis and the underlying parenchyma (Plate I, Figs. 1 and 2; Plate II, Fig. 6). The cells bordering the fissures soon show plasmolysis (Plate I, Fig. 2). So sensitive to the increased water-loss are the chloroplasts that their behavior toward certain stains is changed from normal even when the plasmolysis of the cytoplasm is just beginning. Later the chloroplasts and drying cytoplasm clump in

irregular masses (Plate I, Fig. 3) which stain a dark red with carbol-fuchsin. In the final stage the injured part of the leaf (Plate I, Fig. 4), or the entire leaf, becomes thin and dry. This condition of the leaf is commonly called tipburn.

With slime bacteria present on the leaf, however, the stages following the rupture of the tissues are different. The invading bacteria enter the fissures, multiply, and break down the tissues by the wedging action of the bacterial mass and probably also by dissolving the cell walls (Plate II, Fig. 6). That the ruptured tissues are not always necessary for bacterial invasion and subsequent sliming of the leaf is evident to one who has carefully observed fields of lettuce, at least in Arizona. Small water-soaked spots may be found almost any time when lettuce is heading and sometimes earlier, especially on the lower leaves. These spots evidently result from stomatal infection. Figure 5, Plate II, shows such an infection in an advanced stage.

All commercial varieties of lettuce tried in this State appear to be susceptible to bacterial slime. With a daily range of 30 to 50 degrees Fahrenheit, or even less, there is bound to be a considerable contraction and expansion of the leaf with consequent splitting of the tissues in such succulent plants as lettuce. Experiments in the selection and breeding of a slime-resistant lettuce are needed.

Rot of date fruit (No. 40 A). After a lengthy interruption caused by the presence of scale and by other circumstances, spraying was resumed in the Tempe Date Garden for the purpose of determining the effect on fruit-rotting fungi. Bordeaux mixture was used. During the summer and fall studies of the fruits will be made to ascertain the prevalence and nature of infections.

Texas root rot of cotton (No. 42 A). The work on this project was reduced during the first half of the year because the leader was absent on sabbatical leave.

Progenies of Pima and Acala cotton under test for resistance to Texas root rot (*Phymatotrichum omnivorum*) were planted last spring in root-rot infested soil on the New University Farm near Tucson. Strains showing susceptibility were discarded at harvest, the best progenies were ginned, and the seed was prepared for planting this season. Results with Pima cotton indicate that this variety must be grown elsewhere. The short growing season at the Farm results in immature seed which gives a weak, thin stand and low production. Several strains of Acala appear to be promising from the standpoints of resistance to root rot and yield.

Barriers against the advance of *Phymatotrichum* were placed in an orchard of peach and apricot near Tucson 3 years ago in order to determine the effective life of types of barriers. The barriers prevented the advance of the root-rot fungus for 2 years, but the recent subdivision of the orchard has made further information impossible due to the removal of trees and the erection of buildings.

Cuttings of numerous plants set in ground infested with the root-rot fungus did not survive the infrequent irrigations. Rooted plants of many species whose status in regard to resistance is unknown or doubtful have been planted this spring in order to extend the knowledge of the host range of the root-rot fungus.

Miscellaneous studies (No. 43 S). Galls on a conifer, *Cupressus arizonica*, growing on the campus of the University of Arizona, varied in size from very small swellings to tumors 6 to 9 inches in diameter (Plate IV, Fig. 14). One of the larger galls weighed 1,395 grams. Many galls were hard, but a few spongy ones were found. Hard galls consisted of concentric and eccentric thickenings. The usual disarranged condition of the stelar elements in crown gall was present, in which transverse, longitudinal and oblique aspects showed in the same cross-section (Plate IV, Fig. 17).

From the galls a bacterium was isolated which produced galls on *Ricinus communis*. This bacterium gave, in media, reactions, corresponding to those described for *Phytomonas tumefaciens*.

Tumors of a resinous nature on the conifers, *Pinus sylvestris*, *P. laricio*, and *P. maritima* are referred to by Dufrenoy*. However, they occurred on aerial members; neither the tumors nor the bacterium to which the tumors are attributed agree with descriptions of crown gall and its causal organism. Miles and Brown have found galls on *Juniperus sabina* which they believe are crown galls, but they do not report inoculation studies with the bacterium obtained from this conifer.

Graphiola leaf-spot of the date palm (No. 107 P). The work done on this project during the year was directed to clear up certain points and to permit the project to be written for publication. The principal lines of study were:

(1) A more extensive and thorough review of the literature than had previously been possible. Through the courtesy of Dr. W. T. Swingle, photostatic copies of many French and German publications were made available.

*Dufrenoy, Jean—Sur les tumeurs bacteriennes experimentales de Pins—Compt. rend., t. 169, p. 545. 1919.

(2) A morphological study of all available specimens of the leaf spot from Arizona, California, and the Mediterranean region (the last-mentioned through the kindness of Dr. H. S. Fawcett) which showed that a single species, *Graphiola phoenicis* Poit., attacks the date palm.

(3) A study of the host range of *Graphiola phoenicis* which showed it to be limited to the date palm (*Phoenix dactylifera*), the Canary Island palm (*Phoenix canariensis*), and hybrids between the two. Other palms may have their foliage intermingled with infected palms and remain uninfected.

(4) A study of the geographic distribution and economic importance of the *Graphiola* leaf spot showed it to be more destructive in the relatively humid coastal belt of California, but it may also be severe in the dry interior regions under conditions of high local humidity. The annual development and dissemination of the spores occur during May and June. This year's observations will be included in a forthcoming publication.

Dry root rot of citrus. In cooperation with Dr. H. S. Fawcett of the Citrus Experiment Station, Riverside, California, a study of the dry root rot of citrus is in progress. Various cultures of *Fusarium* spp. isolated from specimens of roots obtained from Arizona and California have been grown in pure culture on different media and inoculated into the roots of healthy orange trees on both sour and sweet stocks. The inoculations were made in January and further study is planned for strains that prove to be pathogenic.

Orchard work in central Arizona. Insistent demands for the investigation of orchards in Yavapai and Coconino counties resulted in the tracing of Texas root rot to an altitude of 3,500 feet. Peach trees are chiefly concerned. In addition to the root-rot there are fire blight, crown-gall, and powdery mildew affecting apple trees; also nematodes on peach trees in limited areas of soil.

Experiments have been carried on during the past year in which new methods were employed in the attempt to control Texas root rot in the orchards. In these experiments the investigators have had the hearty cooperation of the two county agents and the farmers concerned.

Foot rot of peas. Foot rot of peas occurs in central Arizona. Its symptoms include the destruction of the cortex of the root, basal part of the stem, and the brown discoloration of the vascular cylinder in the same regions of the plant. Although the disease is not primarily a wilt, wilting may occur. Infected plants show yellowed leaves followed by the death of the vine.

A *Fusarium* which causes the observed foot rot was isolated last year and studied during the present year. Pure cultures of the fungus inoculated into Canada field peas grown from surface-sterilized seeds in autoclaved soil, caused the foot rot. The same results were obtained more quickly by using a mixed culture of the *Fusarium* and a *Rhizoctonia* associated with it in the field.

Spores from a monosporidial culture of the *Fusarium*, which were inoculated into soil in which healthy pea seedlings were growing, caused the foot-rot disease. The first symptoms of the disease on the roots was the appearance of small, round, brown, freckle-like spots which enlarged and coalesced to form larger lesions (Plate IV, Fig. 15). The infection spread upward from root to stem. Eventually the parenchyma of root and stem decayed in the infected region.

Cultural reactions thus far recorded for the *Fusarium* of foot rot grown from the original monosporidial culture are as follows.

PLATES OF CZAPEK'S SOLUTION AGAR, pH 5.8

Twenty-four-hour cultures at 28° C. showed a gray pionnotes 2 mm. in diameter. At 6 days, growth was scant; central part of pionnotes 18 mm. in diameter, was dull, moist, pinkish buff, on some plates radially streaked with gray. There was a marginal halo of very fine gray hyphae, 14 mm. wide. At 37° C. there was no growth in 6 days.

SLANTS OF POTATO—2 PERCENT DEXTROSE AGAR, pH 5.6

Four-day cultures at 28° C. thinly covered most of the surface of the slant with a dull, moist, tough pionnotes; needle-track a dark vinaceous, slightly elevated ridge from which radiated a dark vinaceous filamentous network becoming gray in the almost invisible margin. At the end of 14 days cultures became rugose at base of needle-track and showed on under surface of slant; upper surface hydrangea to mineral red; under side of slant ox-blood red; no aerial hyphae in most tubes; growth somewhat stronger on this medium at 4 days, and markedly stronger in 14 days, at pH 7 and same temperature.

AUTOCLAVED POTATO

Pionnotes with smooth surface, at 28° C., changed from pinkish buff and light ochraceous salmon in 10-day cultures to rugose, leathery pionnotes hydrangea red on ridges and vinaceous-pink in hollows in 18-day cultures; aerial hyphae, when present, pale gull gray or pale vinaceous to pale pinkish buff.

PLATES OF AUTOCLAVED YELLOW CORN MEAL

In 4 days, at 28° C. pionnotes were 20 × 27 mm.; pale grayish vinaceous with a small spot of avellaneous to wood brown; lower surface of culture clay to tawny olive, no aerial hyphae. In 10 days, growth was 46 × 55 cm.; marginal area pale vinaceous-fawn, vinaceous-gray, to walnut brown; central part buff-pink to walnut brown; under surface buckthorn to Dresden brown; aerial hyphae scant. In 14 days, margin light vinaceous-gray to light vinaceous-lilac; center olive-buff to purplish-vinaceous.

At 37° C. growth ceased when pionnotes was about 5 × 12 mm. and no further growth occurred during 14 days; color shell pink; no aerial hyphae.

PLATES OF AUTOCLAVED RICE

Four-day cultures at 28° C. gave pionnotes 9 mm. in diameter to 8 × 23 mm., moist, glistening, honey yellow; no aerial hyphae on most plates and a small (3 mm. diam.) tuft of delicate, gray, erect hyphae in others. In 16 days growth covered entire surface of plates, raw sienna on margin to antique brown in center; thin growth of aerial hyphae, light vinaceous-fawn, covered greater part of surface to within 1 cm. of the margin and surrounded a gray pulverulent center; lower surface had spots of light orange-yellow. At 37° C. there was no growth in 21 days.

MEASUREMENTS OF SPORES

Measurements of spores from a monosporidial source, in microns, are given in the following table. Three-, four-, and five-septate spores were most numerous and six-septate spores rarest.

Crowngall on the pepper tree. The pepper tree, *Schinus molle*, which is extensively planted in southern Arizona as an ornamental, is killed by Texas root rot (*Phymatotrichum omnivorum*) and more slowly by timber rot (*Inonotus schini*). The first tree to show crowngall was discovered during the year. This tree (Plate III, Fig. 13) was also infected with the root-rot fungus.

Powdery mildew on Philibertia cyanchooides. Conditions this year were favorable for the appearance of powdery mildews. One of the mildews, *Phyllactinia corylea* (Plate III, Fig. 11), was collected on the vine, *Philibertia cyanchooides*. The vine is a species of the milkweed family which probably has not before been recorded as one of the hosts of *Phyllactinia*.

Lettuce drop. Although lettuce drop has occurred in Arizona before,

the disease has never caused significant loss until this year when it destroyed much of the head lettuce on two 40-acre tracts (Plate III, Fig. 9). Sclerotia varying in size (Plate IV, Fig. 16) were abundant on infected plants. The disease is caused by *Sclerotinia sclerotiorum*.

Cytospora canker. Complaints concerning the injury or death of weeping willow, walnut, and pecan trees have resulted in the collection of *Cytospora* cankers from these hosts. Such cankers on pecan trees appear to be unreported, although the hickory is listed as a host of *Cytospora*.

Cytospora on pecan (Plate III, Fig. 10) kills trees to the ground. The fungus is very similar in gross appearance to *Cytospora nivea* on cottonwoods and poplars. It readily attacks the cottonwood when the latter is inoculated with the conidia. The measurements of the conidia more nearly agree with *Cytospora nivea* than with those of the commoner *Cytospora chrysosperma*. On the pecan the fungus produces conidia ranging from 3.18 to 5.9 microns by 0.91 to 2.04 microns, and averaging 4.38 microns by 1.17 microns; the same fungus produces on the cottonwood conidia ranging from 3.72 to 5.58 microns by 0.93 to 1.628 microns and averaging 4.77 microns by 1.32 microns.

Reciprocal cross-inoculations have not been completed since the pecan *Cytospora* came in on April 13 and it has been impossible to procure pecan trees for the purpose of inoculation. However, the successful inoculation of the cottonwood with conidia from the fungus on the pecan and the similarity in appearance of the pycnidia and conidia of the two hosts suggest that the parasites on the two species are one and the same fungus. In this case the planting of cottonwoods adjacent to pecan orchards and the planting of pecan trees near cottonwoods is dangerous.

The *Cytosporas* are generally less active on healthy, thrifty plants; indeed they often refuse to grow on such plants. They frequently enter the host through wounds. Pecan orchards should therefore be carefully pruned, cultivated, and otherwise cared for in order to maintain resistance to the canker disease.

The *Cytospora* on walnut (Plate III, Fig. 8) appeared to be related to injury of the tree by a flat-headed borer. The spore horns of this species of *Cytospora* are brown on the walnut and orange on the cottonwood, to which it may readily be transferred by inoculating the cottonwood with the conidia. Study of the *Cytosporas* mentioned above is progressing in this laboratory.

Soft scald of apple. Soft scald of apple (Plate IV, Fig. 18) is a physiological disease which is likely to cause loss in improperly venti-

lated storehouses. In order to avoid scald, space should be provided between the containers containing the apples, and circulation of air should be provided.

Stylar-end rot of lime. This physiological disease, characterized by a drab discoloration and breakdown of the rind at the stylar end of the lime (Plate III, Fig. 12), was reported once during the year.

Tomato yellows. Tomato yellows (western yellow blight) is well distributed over the State and is perhaps the most important disease of tomatoes in Arizona. Wilt (*Fusarium lycopersici*) is present but as yet causes much less trouble than yellows. The planting of wilt-resistant tomato seed has been encouraged by the Department.

Potato diseases. Encouraging results have been obtained in reducing virus diseases of the potato through the usual methods of planting certified seed and roguing diseased plants. At the same time disinfection of the seed has much reduced black scurf and scab. So far, attention could be given to one potato district only. It is hoped that extension of the work may be possible.

Rust on beans. Crops of beans from the New Mexico line to Nogales in southern Arizona were severely attacked by rust (*Uromyces appendiculatus*) in 1931.

Root knot. Root knot caused by the eel-worm or nematode (*Caconema radiculicola*) is a serious problem in several districts. During the past season it has been encountered on strawberry, grape, fig, peach, rose, and many other plants. Five Washington palms (*Washingtonia filifera*) were killed by root knot (Plate III, Fig. 7) and careful examination of the root system disclosed almost complete destruction of the rootlets.

Wilt-resistant watermelons. In the spring of 1931 seeds of three wilt-resistant watermelons, Iowa Belle, Iowa King, and Pride of Muscatine, were received from the Iowa Agricultural Experiment Station. Some seeds were distributed to county agricultural agents of the State and some were planted on the Old University Farm and in the Horticultural Garden on the Campus. The object was to determine whether the resistance to wilt and the quality of the fruit would be retained by the three varieties under the conditions of soil, climate, and irrigation in Arizona. The results are briefly as follows:

(1) None of the vines wilted in the plots under our observation nor were any complaints of wilt received from cooperators.

(2) The fruits produced by the Pride of Muscatine were generally inferior because white streaks permeated the flesh at the stem end. One exception was noted and seeds were saved from it. Fruits of Iowa Belle and Iowa King were generally of good size and shape, and their flesh was red, firm, sweet, and crisp. A few fruits of the Iowa King variety were "bottle-necked," probably because the condition of the soil or the method of irrigation was at fault since the deformed fruits were chiefly produced on the Campus plot. Some fruits from the wilt-resistant seed were exhibited at the State Fair by County Agricultural Agent C. B. Brown of Tucson and were successful in winning prizes. Wilt-resistant watermelons are receiving a more extensive trial this year, since a large plot has been planted on the New University Farm and much seed has been distributed among cooperating county agricultural agents.

Mycosis in chickens. Upon the request of the Department of Poultry Husbandry an investigation was made of a puzzling mortality of chickens. On one ranch the loss of young chicks was 15 to 33 percent above normal. Post mortem examination of the chicks revealed ulcers (Plate IV, Fig. 19) which penetrated through the mucosa of the gizzard into the musculature. From the ulcers a fungus was isolated which belongs to the Aspergillaceae. *Aspergillus fumigatus* was suspected, but the symptoms, cultural reactions, and certain morphological features of the isolated fungus do not agree.

The fungus which was isolated from the lesions in the gizzard does not affect the respiratory organs of the chick which are chiefly attacked by *Aspergillus fumigatus*; it is pale pinkish buff to august brown on Czapek's solution agar while *Aspergillus fumigatus* is green to almost black; it develops only sexually on all media thus far used, whereas *Aspergillus fumigatus* from mycoses in poultry develops only the conidial stage. Inoculations of healthy chicks with the isolated fungus by dropping 5 cc. of an ascospore suspension into the throat has resulted in infection as high as 100 percent. From the ulcers thus produced the fungus was re-isolated.

In cooperation with the Department of Poultry Husbandry the study is to be continued.

DESCRIPTION OF PLATES

The drawings were made with aid of the camera lucida. They illustrate parts of cross sections of lettuce leaves which were obtained from a field going with slime and tipburn. The material was killed in very small pieces in chromo-acetic acid, run through a close series of alcohols, and stained with light-green carbol-fuchsin and iron-alumhaematoxylin. The varieties of lettuce represented in the drawings are Jagger's Imperial Number 2 and Big Boston. Descriptions under the numbers on Plates III and IV are adequate for the photographs.

PLATE I

All drawings in this plate were made from sections of leaves of the lettuce variety, Jagger's Imperial Number 2.

- Fig. 1—Part of a cross section of a leaf showing fissures in the parenchyma. X 85.
- Fig. 2—Appearance of cells in a lettuce leaf bordering a fissure like those shown in the preceding drawing. Plasmolysis is marked. X 778.
- Fig. 3—Later stage in the plasmolysis of the leaf cells. The chloroplasts and cytoplasm form clumps which stain dark red with carbol-fuchsin. X 1489.
- Fig. 4—Cross-section through a "tipburn" spot in a lettuce leaf. Plasmolysis is proceeding more rapidly in that part of the leaf represented by the upper part of the drawing. X 136.

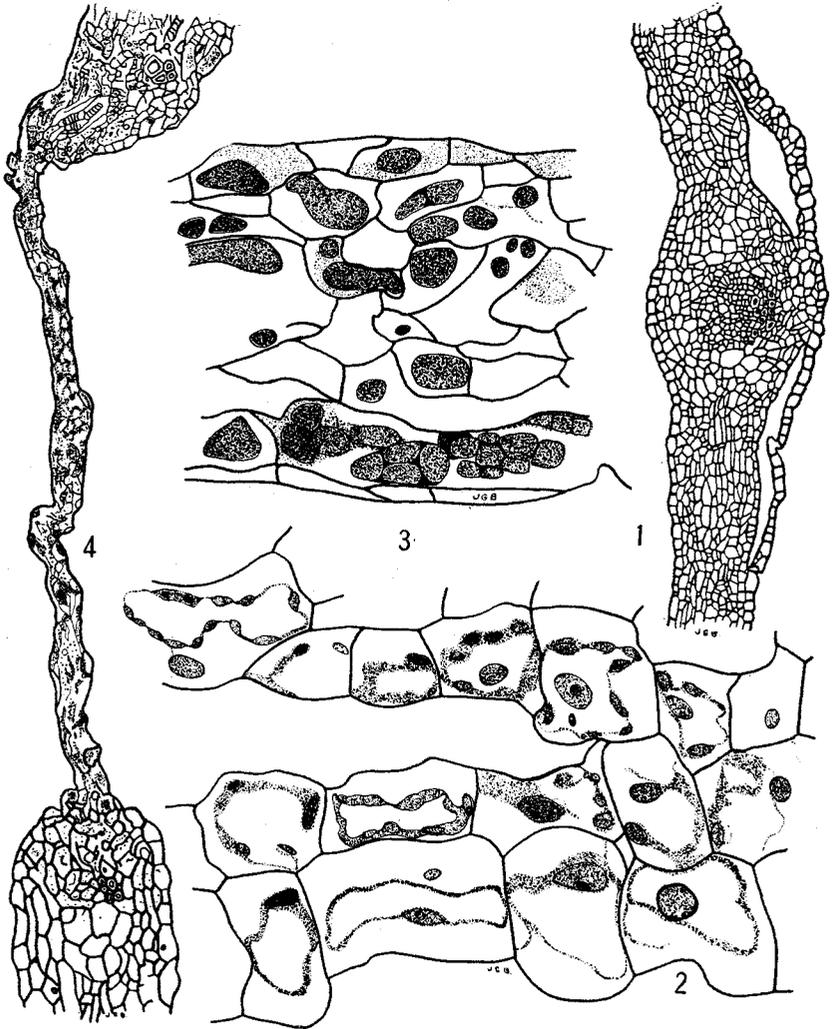


PLATE I

PLATE II

- Fig. 5—Section through a slime spot in a lettuce leaf of Jagger's Imperial Number 2. The remains of a stomatal cell (x) and the more extensive collapse of the bacteria-invaded tissues near it indicate a stomatal infection. X 407.
- Fig. 6—Section through a slime spot in a leaf of the Big Boston variety of lettuce. A fissure through and under the epidermis has been invaded by bacteria. Disintegration of the tissues into slime is proceeding both by the wedging action of bacterial masses and the dissolving of the cell walls. X 460.

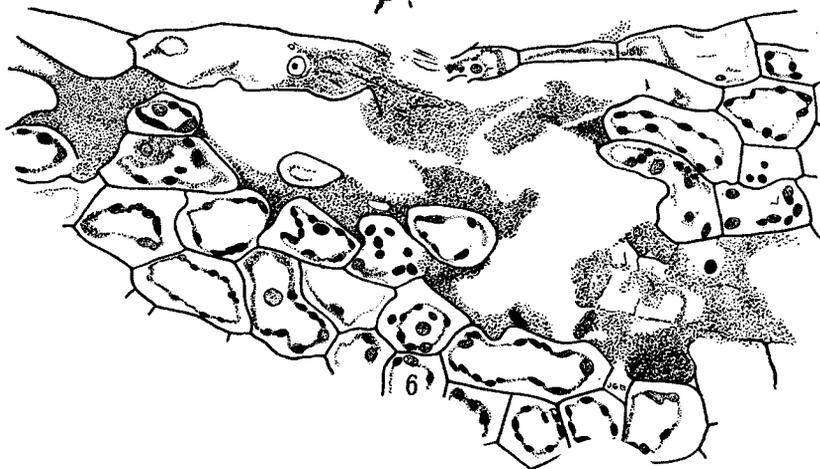
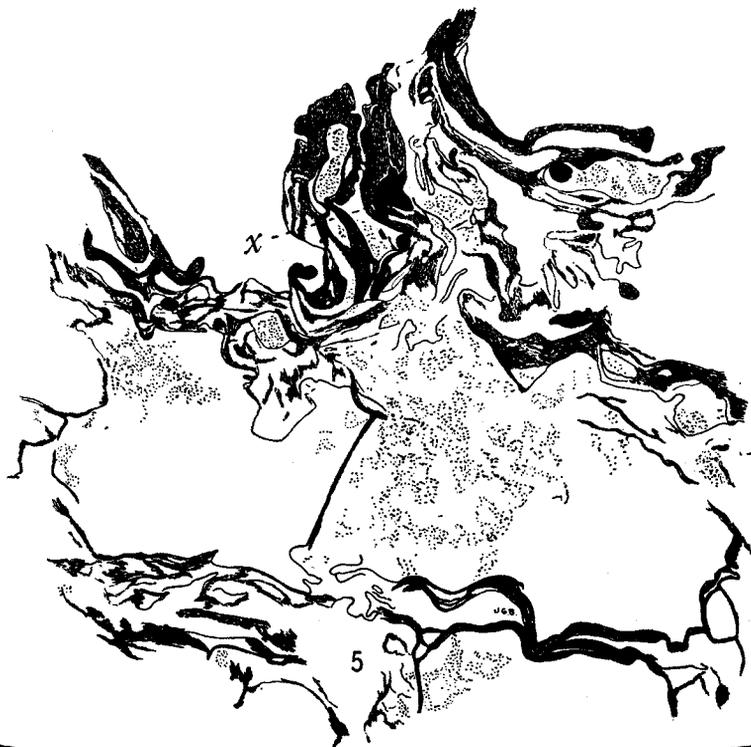


PLATE II

PLATE III

- Fig. 7—Root knot on roots of the Washingtonia palm, *Washingtonia filifera*. Small rootlets are often entirely destroyed.
- Fig. 8—Spore vessels (pycnidia) on the bark of the black walnut, *Juglans nigra*. This disease is canker caused by *Cytospora sp.*
- Fig. 9—View of part of a 40-acre field of lettuce which was vigorously attacked by lettuce drop (*Sclerotinia sclerotiorum*).
- Fig. 10—Enlarged photograph of bark from a pecan tree killed to the ground by canker (*Cytospora sp.*). Spore horns of the fungus show at 'y'.
- Fig. 11—Powdery mildew (*Phyllactinia corylea*) on a leaf of the vine, *Philibertia cyanchoides*.
- Fig. 12—Stylar end-rot, a physiological disease, on lime.
- Fig. 13—Crowngall on roots of the pepper tree, *Schinus molle*, a new host for the disease.

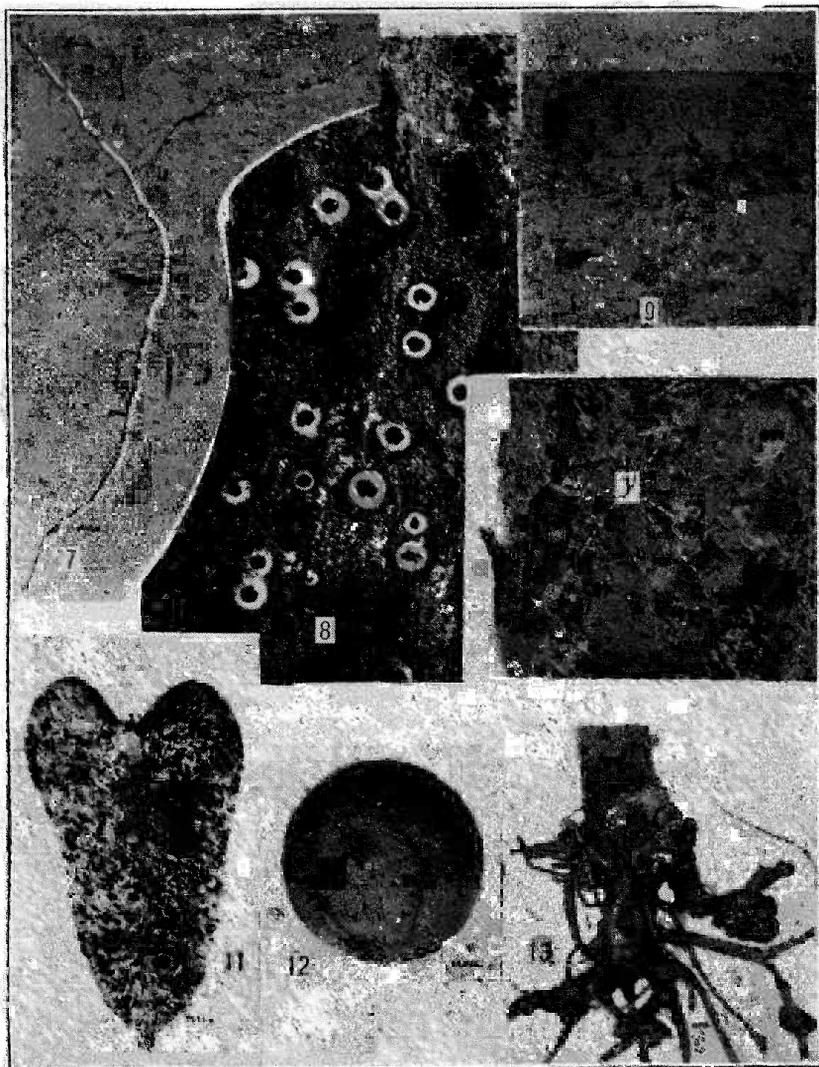


PLATE III

PLATE IV

- Fig. 14—Crowngall on the roots of *Cupressus arizonica*. Small gall at "a" and larger ones at "b." The galls are framed with cotton wool.
- Fig. 15—Foot-rot on a pea seedling. a. Small freckle-like brown spots constituting an early symptom; b. well-developed lesion; c. mycelium of *Fusarium* which causes the rot.
- Fig. 16—Sclerotia of the fungus, *Sclerotinia sclerotiorum*, which causes lettuce drop. The sclerotia or resting bodies were collected in a field in Arizona.
- Fig. 17—Photomicrograph of part of a cross-section through a gall on the root of the Arizona Cypress, *Cupressus arizonica*. The tracheids are disarranged, some showing longitudinal view, others a transverse view, and still others an oblique view.
- Fig. 18—Photograph of an apple illustrating soft scald, a physiological disease, affecting apples stored in ill-ventilated houses. Considerable loss from this disease has resulted in the apple districts of northern Arizona.
- Fig. 19—Photograph of an ulcer in the gizzard of a chick which resulted from an infection with a fungus. The ulcer, "u," was found in a natural infection.

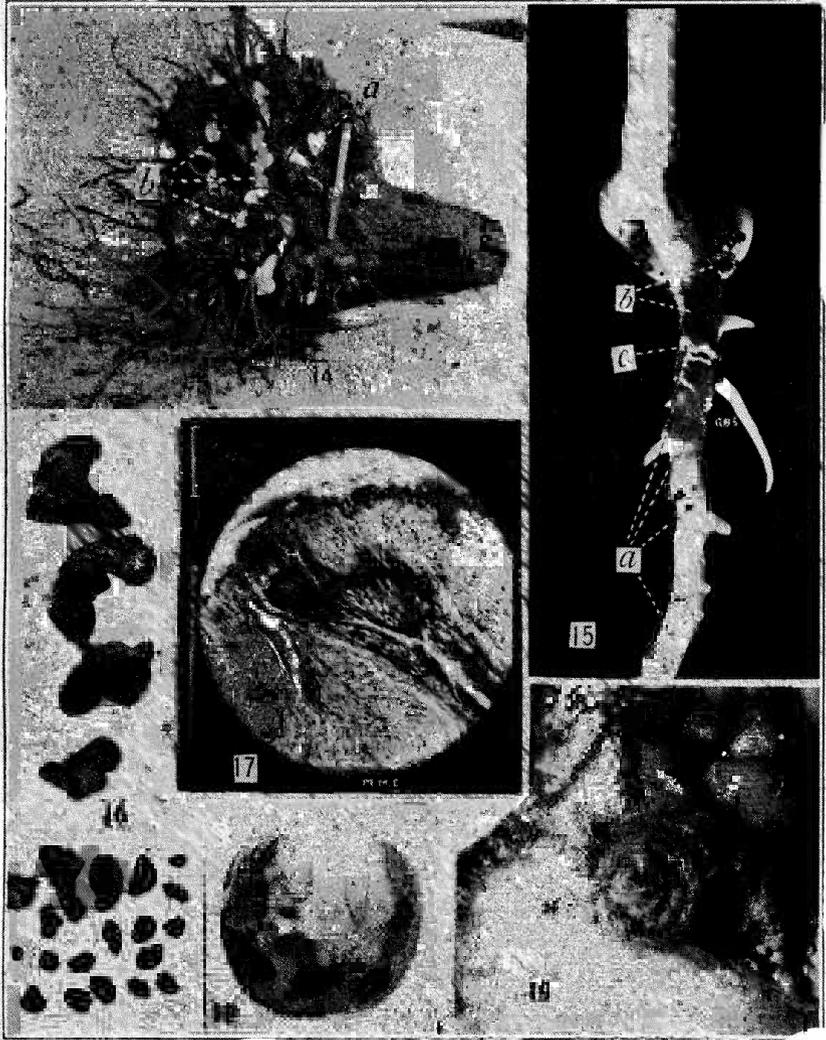


PLATE IV

POULTRY HUSBANDRY

HARRY EMBLETON

The demands upon the time of the members of the Poultry Department are numerous and varied and logically group themselves as follows: Research, instruction, extension, and service work. While the first three are self-explanatory, the last embraces the following: Information given to office callers, farm visits by staff members, the inspection and diagnosis of diseased birds, and state and county fair activities.

There are many demands for poultry information under Southwestern conditions upon which there is little knowledge. This necessitates original work in order that this information may be made available. The planning, assembling, and carrying out of this work in such a way that it will be accurate and beyond question requires much painstaking time and care in addition to an elaborate system of record keeping. Following is a resumé of some of the experimental work carried on by this department during the past fiscal year.

Poultry housing experiments: Housing vs. no-housing (No. 91 S). The house is the home of the hen. She uses the same abode in winter and summer. In Arizona this is a very important factor since the temperature reaches great extremes at different seasons.

The housed lot had access to a metal house of a type that is in general use in this section, while the no-house group were forced to roost on outdoor tables that were entirely exposed and unprotected. A summary of results for the 3½ years of work so far completed follows:

1. Feed consumption per dozen eggs was 0.78 pound less in the housed group.
2. There was a difference in mortality of 7.64 percent in favor of the no-house lot.
3. Average annual egg production per bird was greater in the housed lot for 2 of the 3 completed years. This is also the case so far in this year's work.
4. Precipitation did not appear to affect production in the no-house pen though it may have influenced the food consumption.
5. Temperature is largely responsible for the success or failure of the houseless method of keeping poultry in southern Arizona.

Egg-laying contest (No. 153 S). Our egg-laying contest, now in its tenth year, is a medium through which a great deal of information is being accumulated without cost to the Station, for the contest is self-supporting. Information is being obtained along the following lines:

Monthly distribution of egg production
Feed cost per dozen eggs
Feed cost per year for various breeds
Varying feed cost for breeds
Effect of temperature on production
Relation of feed cost and production
Relation of feed cost and gross returns
Variation of feed consumption with volume of production
Distribution of production with varying values of production
For further information on this project, see page 45.

Foundation for experimental work (No. 46 S). 1. Pearl's work indicated that egg production was transmitted from the dam through the son to the offspring. A check of the progeny produced during the spring of 1923 at this Station showed an average egg production of 112 eggs with the high individual laying 182 eggs. With the use of a male from a high-producing female the average in the offspring was raised to 191 eggs the following year with a high individual of 267 eggs. There was no check made on all the pullets in the third generation, but the fact that our best pen from this generation averaged 268 eggs, the next best 251 eggs, the next 246 eggs, and another 237 eggs, comprising nearly 200 individuals, and the fact that the high bird laid 310 eggs, indicated the results.

Since then a definite systematic check on the progeny from pens in which high producing males were used not only does not show an increase but a serious decrease in every case. This held true whether the breed was White Leghorns, Rhode Island Reds, or Barred Rocks.

For future work it is planned to continue the testing of progeny but with this difference: We will have both a first and second generation from the same sire to note whether results will be different in the second generation.

2. A study of inbreeding and outcrossing on egg production and vigor. Four distinct blood lines of proved production were perpetuated within themselves, each blood line being kept intact by mating a male of the first generation back to the original dam and daughters, with the loss in egg production and vigor, as indicated below. At the end of the third generation outcrossing between the four blood lines was resorted to, with an increase in egg production and vigor as a result.

1924-25 158 EGGS ARE FOUNDATION FOR PEN 117

<i>Year</i>	<i>Pen</i>	<i>No. started</i>	<i>Av. production</i>	<i>Mortality</i>
1925-26	117	22	193	3
	118	14	220	1
	119	25	196	4
	120	23	206	2
1926-27	117	15	191	8
	118	14	156	5
	119	6	169	3
	120	14	167	6
1927-28	117	15	169	6
	118	8	135	3
	119	Defunct	—	—
	120	17	133	12
Change to outcrossing				
1928-29	117	21	162	2
	118	19	170	3
	119	Defunct	—	—
	120	20	183	0
1929-30	117	20	195	2
	118	19	210	1
	119	Defunct	—	—
	120	19	221	2
1930-31	Work ruined by intestinal parasite attacks.			

A comparison of certain local feeds (No. 90 S). A tankage-meal being produced by a firm in Phoenix from wild range horses seemed to have promise as a protein supplement as it analyzed 60 percent protein and was being placed on the market for \$3.25 compared to a 54-percent protein meat-meal with a cost of \$5.00 which was in general use. Moreover, a mixture of fish meal and kelp known as Manamar was being sold with great claims for it in certain sections of the State.

Inasmuch as we are having many inquiries regarding these materials it was felt worth while to get some first-hand information regarding

them. Our work from April 1 to September 1, 1931 has given the following results:

	<i>Egg production</i>	<i>Feed consumption</i>	<i>Mortality Pct.</i>
Check pen (U. of A. ration)	76	32	33
Horse-meat meal	61	28	40
Manamar	64	26	25

Apparently our own ration was better than the other two rations in question for producing eggs. The University of Arizona ration was apparently more palatable if greater feed consumption can be taken as an indication. The heaviest losses were in the horse-meat-meal pen and the next in the University of Arizona ration pen.

The exceptionally high mortality throughout all pens was undoubtedly due in part to a heavy infestation of worms. As this high mortality and the abnormal condition of the birds that lived make the comparative value of this work questionable, it was repeated in 1931-32.

PERIOD FROM OCTOBER 1, 1931 TO MARCH 1, 1932

	<i>Egg production</i>	<i>Feed consumption</i>	<i>Mortality Pct.</i>
Check pen (U. of A. ration)	70	32	10.5
Horse-meat meal	62	36	6.2
Manamar	62	30	3.2

All stock used in this work had been wormed four times before being placed in the pens, thereby accounting for the lower mortalities.

This particular meat meal and Manamar again did not prove as efficient in promoting egg production as did our regular ration. The feed consumption and mortality varied from the previous results.

A number of interesting preliminary tests have been conducted during the past year. They are as follows:

Rearing chicks in confinement. Due to contamination of the poultry yards it is becoming more difficult to control diseases and intestinal parasites in chicks. Wire floors and rearing of chicks in confinement suggests a method of partially solving this difficulty.

A preliminary test of 8 weeks was run in which three lots of 279 chicks each were involved.

Lot 1—wire floor and wire sun porch.

Lot 2—concrete floor and concrete sun porch.

Lot 3—outside range.

A summary showed the following:

1. The rate of growth was approximately equal in all pens. Two-tenths of one ounce per bird being the average variation of the pens.
2. Mortality in the wire floor pens was heavy due to an outbreak of cannibalism.
3. The concrete floor pens were difficult to clean and required considerably more labor.
4. Feathering was poor in both confined lots.
5. Confinement did not increase the food consumption.

Poultry feeding utilizing Arizona grains. Probably the best way to market a part of Arizona's large barley and red-milo crops is through poultry meat and eggs. This test includes four rations the basis of which are as follows: No. 1, yellow corn; No. 2, barley; No. 3, check (U. of A. ration); and No. 4, red-milo maize.

The pen production to date (6 months) is as follows: No. 1—2225 eggs; No. 2—1818 eggs; No. 3—2355 eggs; and No. 4—2030 eggs.

The amount of feed necessary to produce a dozen eggs is as follows: No. 1, 5.2 pounds; No. 2, 5.9 pounds; No. 3, 4.9 pounds, and No. 4, 5.4 pounds.

The utilization of Arizona grains in poultry ration will depend upon the cost of producing a dozen eggs. To date, the cost has been slightly higher with Arizona produced grains than with outside feeds.

Battery brooding rations. In many cases of battery-reared chicks, difficulty has been encountered. The tendons become enlarged and misplaced. It has been felt that close confinement together with certain elements in the ration were responsible for this condition. The elimination of bone meal and the replacing of one-half the meat scrap allowance with fish meal has so far in this test taken care of this condition. Further work will have to be done before definite conclusions can be drawn.

Ulcerated gizzards. In cooperation with the Plant Pathology Department, an unusual poultry-disease problem is being given considerable attention. A review of the literature fails to reveal any previous work on this subject. While this abnormality (ulcerated gizzard) may be of strictly local application, it is of great economic importance to the flocks where it has appeared. Specimens having ulcerated gizzards have been secured from three widely separated parts of the State. In each instance an aspergillus fungus has been isolated which has proved highly infectious to young chicks. This work is being continued.

RANGE ECOLOGY

W. G. MCGINNIES AND A. A. NICHOL

The Range Ecology Department has been strengthened during the past year by the transfer of Mr. A. A. Nichol as assistant professor, (two-thirds time) and the addition of Mr. L. D. Love as research assistant, and Mr. Homer Martin as assistant in Range Ecology.

Work during the past year has been largely concentrated on the establishment and development of a study of the desert grassland areas of Arizona. A base station has been established in cooperation with the United States Forest Service on the Santa Rita Experimental Range, 35 miles south of Tucson. This site was chosen as being typical of the desert grassland and at the same time it offers excellent opportunity for coordinated work between research agencies of the Forest Service and the University.

The ultimate aim of the present study of desert grassland is to determine the time and intensity of use and management of the range which will result in the most efficient use of the range from the standpoint of the individual stockman and for the best interests of the State as a whole.

Previous studies have shown that the reaction of vegetation to different periods and intensities of grazing is dependent upon other factors such as variations in temperature, amount and seasonal distribution of rainfall, humidity, and the chemical and physical composition of the soils. These and other interacting factors influence forage production in various degrees and the reaction of a given plant species to grazing will vary according to the various combinations of these factors.

In order to measure the influence of these factors, a meteorological station was established to measure sunlight intensity and duration; evaporation; relative humidity and saturation deficit; air and soil temperatures; and soil moisture. The station also includes equipment for the measurement of the water requirements of the more important desert grassland species. During the past year appreciable differences were noted in the rates of water use and water requirements of the various species, but several years study will be necessary before the results can be published.

Adjacent to this station are three 2-acre plots representing (1) grazing by cattle and rodents, (2) grazing by rodents, (3) protection from grazing. A similar series of plots has been under observation since 1918 about 2 miles from the station. These plots have been intensively mapped and the growth and abundance of various species measured.

The above projects represent long time studies as adequate conclu-

sions cannot be reached until the seasonal and yearly variations have been studied and the cumulative influence of grazing determined.

For a number of years the Range Ecology Department has been carrying on studies in regard to rayless goldenrod or burro weed as a noxious and poisonous range weed. These studies have been mainly directed toward the control and eradication of this pest. It appears that the distribution and spread of rayless goldenrod in the past was largely determined by fires. Heavy grazing has no doubt allowed opportunity for it to gain a stronger foothold on many ranges but grazing alone is not responsible for its increase during the past few years. This is shown by the increase of rayless goldenrod in partially and totally protected plots. On the other hand, rayless goldenrod is very susceptible to death by fire.

It has been found that rayless goldenrod can be eradicated by burning and by the use of chemical sprays such as a 5-percent solution of sulphuric acid, but on many ranges the expense of such eradication is too great to be economic. For this reason the study has been continued with the hope of finding less expensive means of eradication. Especial attention is being given to the growth requirements, life history, and natural enemies of this weed to see if a more or less natural control can be developed.

A preliminary study of the sheep and goat ranges within the State was completed during the year and it is expected that these results will be published in the near future.

In cooperation with the Animal Husbandry Department, studies were made on the livestock losses from poisonous plants and the foraging habits of cattle. The discussion of these projects is included in the report of that department.

FINANCIAL STATEMENT, 1931-1932

Herewith is submitted a report of the receipts and expenditures of the Arizona Agricultural Experiment Station for the fiscal year ended June 30, 1932.

RECEIPTS

	Hatch fund	Adams fund	Purnell fund	State funds
Received from the Treasurer of the United States.....	\$15,000.00	\$15,000.00	\$60,000.00	
State appropriations:				
Main station.....				\$73,869.65
Substations.....				37,343.86
Receipts from sales.....				2,681.25
Totals.....	\$15,000.00	\$15,000.00	\$60,000.00	\$113,894.76

EXPENDITURES

Salaries	\$14,241.01	\$10,935.84	\$40,950.72	\$51,367.95
Labor	219.64	2,048.00	6,094.91	16,018.77
Stationery & office supplies..		11.49	82.72	681.59
Scientific supplies,				
consumable	3.11	276.47	2,406.88	2,117.15
Feeding stuffs			725.07	1,125.10
Sundry supplies.....	18.35	152.19	684.51	2,418.89
Fertilizer & irrig. water.....		13.50	739.31	2,483.85
Communication service.....	.30	6.66	12.04	771.29
Travel expense.....	289.96	964.36	3,719.89	4,740.07
Transportation of things.....		56.05	367.06	507.98
Publications	224.13		535.89	4,846.79
Heat, light, water & power..			118.71	670.37
Furniture & Fixtures.....		10.33	455.81	6,559.09
Library			3.87	
Scientific equipment		351.63	1,828.76	1,142.00
Livestock (permanent)				1,488.01
Livestock (Feed expt.).....				8,177.97
Tools and machinery.....	3.50	8.06	859.28	4,593.03
Buildings & land.....		141.31	406.55	3,388.84
Contingent expenses.....		24.11	10.07	579.08
Unexpended balance.....				216.94
Totals.....	\$15,000.00	\$15,000.00	\$60,000.00	\$113,894.76